DEVELOPMENT OF A SYSTEM TO DETERMINE THE ECONOMICALLY OPTIMAL COMBINATION OF HOUSING FOR AN AIR FORCE INSTALLATION

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THESIS

Presented to the Faculty of the Graduate School of Engineering of the

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Engineering and Environmental Management

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John E. Hendrix

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Abstract

The United States Military is faced with the decision of how to house it's military members and their families. The three options available to house these families are: 1) utilize existing on-base housing; 2) build new on-base housing; or, 3) compensate a military family monetarily to find housing off-base. This research focused on the development of a tool to aid the decision maker in determining what combination of the three options is economically optimal for an individual Air Force Installation. The model developed incorporates the costs associated to the local area and conditions at the specific installation to determine the cost associated with each of the three housing options.

Current Air Force Policy is to house military families Off-Base once all existing housing On-Base is occupied. Only if the local community can not meet the housing requirements of the Air Force Installation will funds be appropriated to build new housing. This current policy forces housing decisions to be made without the benefit of understanding the economically optimal combination. The model developed identifies this optimal combination to the user, as well as the savings to Installation if it is used. By changing the input into the model, any Air Force Installation could identify the economically optimal housing strategy. Performing sensitivity analysis on the variables used in the decision process will display the effect of any changes in the value of the input variables. Overall, the model provides a decision tool that can be used to make better informed decisions and can be easily manipulated to produce the economically optimal combination of housing for any Air Force Installation.

Development of a System to Determine the Economically Optimal Combination of Housing for an Air Force Installation

I. Introduction

1.1 Background

The United States Military has always been concerned with housing its military members and their families. In order to have soldiers focused on their primary mission of defending the nation, the families of these soldiers must be cared for adequately. This care starts with the housing of military families. Once the families of military members are housed, their full attention can be given to the important jobs that they perform. While the housing of these military families is an important service of the military, each branch of the military is also forced to operate under a financial budget each year. Determining the least expensive combination of On and Off-Base housing for military families at an Air Force Installation could help to decrease expenses.

Currently, a Housing Market Analysis (HMA) is performed to determine if a surplus or deficit of housing exists in the local area of the base. This surplus or deficit is then used to determine what and where renovations, demolitions, or new construction for On-Base housing is needed. A long term construction plan can then be derived called the Housing Community Plan. Integrating the Housing Market Analysis and Housing Community Plan into a decision model would allow the Air Force to optimize its return on investment.

Current DoD guidance states that the local community should be the first source for satisfying the demand for housing generated by military families once all On-Base housing is occupied. Only if the local community can not meet the demand of the military families will funds

be appropriated to build new On-Base housing. Using a decision model to determine the economically optimal combination of housing for an Air Force Installation would help the Air Force house their military families in the most economically efficient manner possible.

1.2 Problem Statement

There is no convenient tool to determine the economically optimal combination of existing On-Base Family Housing, new On-Base Family Housing, and Off-Base housing at an Air Force Installation based on the existing economic conditions. A model that optimizes the housing combination for an individual installation could be used to determine where new construction funds should be appropriated and where it would be more economical to house personnel Off-base. The current Air Force Housing Strategy is "to look to the private sector first" when all of the existing On-Base housing is occupied. "Only when the market cannot meet the Air Force requirements will housing investments be considered" [AFHMA Conference, 1996]. This strategy may be wasting funds if it were cheaper to build new On-Base housing than to pay a military family to live Off-Base. In addition, there could be cases where the cost of maintenance of existing On-Base housing is greater than the cost of building new housing. In order to determine which housing option would be the least expensive to use, an economic comparison of the three options should be performed.

When performing an economic comparison of the three options, there are variables which may change depending on the location of the installation. One of the most important variables is the age of the existing housing On-Base. As a house ages over the years, maintenance costs rise as things start to wear out and need replacing. Knowing the age of the housing at the installation is essential to determining the maintenance expense for that particular housing. It is also

important to know the number of units at the installation associated with that age. There may be several different housing areas that are used to house military members of the same rank. The exact number of units in all of the individual housing groups is needed along with their ages for the entire installation in order to determine which housing groups should be used. These two variables along with many others are needed in the construction of a model that will determine the least cost combination of housing.

The following variables are used in this economic analysis:

- The availability of Off-Base housing (determined in the HMA)
- Number of Military Families at the base
- Number of Mission Essential Military Personnel with families who must live On-Base
- The Amount of existing On-Base housing
- Age of the Existing Housing
- Years since last Revitalization
- Years until next Revitalization
- Construction Costs of New On-Base housing
- Revitalization Costs of housing
- Demolition Cost of housing
- Average Cost of Maintenance
- Housing Factor
- Area Cost Factor
- Interest Rate
- Inflation Rate

- Amount of VHA & BAQ
- Yearly Increase in VHA & BAQ

The model built in this thesis identifies what existing housing groups should be used, how many housing units need to be built, and how many families should be housed Off-Base. The model further compares the combination identified as the least cost option to the current Air Force strategy by using their respective annualized cost over the next 65 years. The comparison of these two annualized costs will show the potential annualized savings to the installation.

1.3 Research Objectives and Scope

The research objective for this study is to construct a user friendly analysis tool that will determine the economically optimal combination of housing for an Air Force Installation.. The decision tool should be able to adapt to any installation in the Air Force by allowing the user to change many of the installation specific variables.

The characteristic of adaptability will also allow this tool to be used for other branches of the United States Military as well as in the civilian arena. Taking the economic conditions of the area in question as input into the model, different housing combinations could result for each different location that the tool is applied. Identifying the economically optimal combination of housing for each installation would ensure that the funds for housing Air Force families be spent in the most economically efficient manner.

1.4 Approach

The analysis tool is based upon an economic model that will apply accepted economic equations which incorporate the economic conditions of the area in question. Using a Microsoft

Excel® spreadsheet, the user will be required to input the data associated to the installation under study. Once this data is input into the model, the cost of each option of housing will be calculated, and the least cost combination of housing will be formed. The model will identify which housing groups should be used and which ones should not. The output of the model will also consist of two different annualized costs. Both the expected value of the annualized cost of housing over the next 65 years for the optimal combination and for the current Air Force strategy will be produced. The comparison of the two calculated annualized costs (optimal combination and current strategy) will show the potential savings to the installation.

Once the economically optimal combination has been identified, sensitivity analysis can be performed on the input variables of the model. The sensitivity analysis will determine how sensitive the decision is to changes in the key economic variables. Using this model to determine the optimal combination of housing and the sensitivity analysis to determine which variables are most influential allows the user of the model to investigate how changes in variables will effect the decision.

1.5 Overview

In chapter 2, the current method of determining base housing will be discussed. An overview of decision analysis and economic analysis techniques needed in this study will be addressed. Chapter 3 discusses the development of the model. The inputs to the model and how they are used will be reviewed. Chapter 4 will discuss the analysis of the results using data from Edwards Air Force Base. In Chapter 5 conclusions are drawn and recommendations for follow-on work are presented.

II. Background

2.1 Introduction

The purpose of this Chapter is to review the economic and decision analysis techniques needed to determine the economically optimal combination of Military Family Housing (MFH) to provide on an Air Force Installation. In this chapter, each option of housing a military family will be investigated in order to determine what variables are needed to calculate the cost. The Air Force's current method of determining the combination of MFH to provide is constrained by policy from identifying the economically optimal solution. To accurately determine the optimal combination of housing to provide, it would be critical for the decision makers to know the least cost combination of On-Base and Off-Base housing. The model developed in this thesis will inform the decision makers of that least cost combination of housing.

The issues addressed in this chapter are: 1) What are the options available to house a military family, 2) What are the limitations of the current method of determining the combination of Air Force military family housing, 3) How can the economically optimal combination of housing be determined, 4) What information is needed in the determination of the cost of each housing option and how can these costs be compared, and 5) Where can the needed information be found to calculate the cost of the housing options.

2.2 Options Available to House Military Families

Providing housing for military families at an Air Force Installation is an important service to keep military members focused on their primary mission. When housing a military family, there

are three options available to the installation in order to provide an acceptable quality of living. The three options are:

1) **Building New On-Base Housing** - If all of the existing On-Base housing is occupied, new housing may be built.
2) **Maintenance of Existing On-Base Housing** - A military family may be housed in an existing house On-Base.
3) **Housing Military Families Off-Base** - It is also possible to pay a military member a housing allowance and have the military family find housing Off-Base.

There are conditions which would either require one option of housing to be used, or eliminate the use of one of the options. One condition that would eliminate the option of housing military families Off-Base would be if there were not enough Off-Base housing units available to meet the demand of the Air Force Installation. In that case, the military families must be housed in existing On-Base housing or new On-Base housing would have to be built. Another condition arises when using existing On-Base housing, this option can only be utilized until all of the On-Base housing units available are occupied. Any additional families would have to be housed by one of the other options.

There are also different costs associated to each of the three options. When comparing the option of building new On-Base housing to utilizing existing On-Base housing, the first cost incurred when building a new house would be the demolition cost of the old house. Once the old house is demolished, there would be a construction cost and then maintenance costs over the lifetime of the house. Maintaining this new housing will require that the house is renovated over time to ensure that the systems in the house are up to date and working efficiently.

Utilizing the existing housing On-Base also requires that the housing be maintained efficiently and renovated when necessary. Like the costs associated with the new housing, the cost of maintaining this housing will increase over the years as more maintenance is required on the aging houses.

When calculating the cost of housing a military family Off-Base, the demolition cost of the existing housing must be considered. To compare the costs of utilizing an existing house to the option of housing a family Off-Base the demolition cost is used to get an accurate comparison; however, the demolition cost is not used when a utilized house is not demolished. In addition to the demolition cost, housing military families Off-Base requires those families be paid Basic Allowance for Quarters (BAQ) and a Variable Housing Allowance (VHA). The amount paid to the military member for BAQ is not location dependent and will only vary according to the rank of the military member and dependent status. VHA is location dependent and will vary depending on where the installation is located as well as the rank of the military member and dependent status. These two costs (VHA and BAQ) combine to total the amount paid to the military member for living Off-Base.

2.3 Current Procedure

The current procedure of determining the amount of On-Base military family housing to provide is based on the available housing in the community that meets the requirements of the different pay grades. The installation first utilizes the existing On-Base housing and then looks to the local community to house the additional families. "The objective for Air Force Housing is to look to the private sector first. Only when the market cannot meet the Air Force requirements will housing investments be considered." [AFHMA Conference, 1996]. The Housing Market

Analysis (HMA) determines the amount of housing available in the local community that meets the "Air Force standards for affordability, location, quality, and size" for the pay grade in question [HMA, Edwards AFB, 1994]. Only if the local community can not supply enough housing, does the installation consider requesting funds to build new housing On-Base. From the current Air Force Strategy, the option of building new housing On-Base is never even considered unless the local community can not support the additional Air Force families which can not be housed On-Base.

The biggest shortfall of the current procedure of determining the combination of housing to use at an Air Force Installation is that the installation specific optimal strategy is never considered because of the current centralized policy. Under the current procedure the cost of each possible option is not calculated; therefore, there is no way to economically compare the three options available. In some cases, the cost of paying a military member to live Off-Base could be more expensive than the cost of building new housing. There may also be cases where the housing maintained On-Base has not been renovated in so many years that it is less expensive to build new housing than to maintain the existing housing. This information can be calculated and used by the decision makers to assist them in determining the best combination of housing to provide. With the Air Force trying to decrease expenditures, the economically optimal combination of housing should be known by the decision makers who determine what combination of housing to use at Air Force Installations.

2.4 Determination of the Economically Optimal Combination of Military Family Housing

In order to determine the economically optimal combination of military family housing to provide at an Air Force Installation, a way of comparing the cost of each option must be

identified. Each housing option spans a certain length of time in which funds are committed. For example, the housing option of paying a military member to live Off-Base is a monthly commitment of funds to that military member. Building New On-Base housing commits funds to constructing a house and maintaining that house over a much longer period of time. The expected lifetime of a new house in AFMC has been determined to be 65 years with two revitalizations [Jameson; 1997]. The first revitalization should occur at the 25 year point in the life of the house, and the second should occur at the 45 year point. These revitalizations are designed to bring the house back to the quality of a new home.

The time commitment of funds for housing military members either Off-Base or building new On-Base housing is fairly constant. However, the time commitment for funds using existing On-Base housing will vary depending on the age of the housing. In order to economically compare the cost of each option, a consistent time period must be used. The time period chosen in this study is the 65 year life expectancy of a new home. The cost for housing a military family Off-Base can be calculated over that 65 year time period in order to compare it to the cost of building a new home. This time period will cover the life remaining in the existing On-Base housing. Once the existing housing reaches the age of 65 years, it will be assumed that new housing will be built to replace the retired housing. This new housing built after the expiration of the existing housing will cover the remaining time period of the study.

Using the 65 year time period discussed above, the cost of each option can be calculated from the economic conditions of the local area. Annualizing the cost of each option will allow the three possibilities to be compared over the same time period. The least cost combination can then be determined using the constraints of each option. For example, the least cost option may be to

maintain the existing On-Base housing, but there must be enough units to house everyone. Once the On-Base housing is full, the least costly of the remaining two options must then be used.

With this cost information the decision makers will make decisions based on economics instead of simply on what the policy states. This procedure discussed above uses both economic analysis and decision analysis in the calculation of the optimal combination of housing. The details of each of these types of analysis used in this procedure is discussed in the following subsections.

2.4.1 Economic Analysis

The economic analysis refers to using economic principles to determine the cost of each possible housing option. The calculations performed in this study are based on well known and accepted economic principles applied to the economic conditions of the installation under study. The method of comparison is to annualize the cost of each option over the 65 year time period and compare results. To describe the equations used in this economic analysis, each option of housing will be presented with a corresponding description of how the cost is to be calculated.

Building New On-Base Housing:

The first option to be discussed is building new On-Base housing. In order to determine the annualized cost of this option over the next 65 years, the cost for each year needs to be calculated. There will be a demolition cost of the existing house (if applicable) and construction cost of the new house in the first year of the house's life (year 1), and some type of maintenance cost for the remaining 64 years. When the annual costs are known, they must then be inflated to

apply to the year in which they occur. The equation used to inflate the present value to the appropriate future value is shown below [Canada, 1996: Table 2-1]:

$$FV = PV(1+f)^n \qquad \text{(equation 2.1)}$$

FV = future value
PV = present value
f = inflation rate
n = the time period in question

The time period n in equation 2.1 would correspond to the number of years in the future that the cost occurs. Applying the inflation rate to the yearly costs will show the actual funds that must be spent in the corresponding year. However, the application of the inflation rate is only part of the process.

Once the actual costs and times have been determined, they must then be discounted by the interest rate to make comparisons possible. This study uses the FY 1997 Revised Inflation Guidance to obtain the recommended interest and inflation rates [DoD, 1997]. Discounting the future value found above by the recommended interest rate will determine the present value. The equation used for discounting is [Canada, 1996: Table 2-1]:

$$PV = FV(1+i)^{-n} \qquad \text{(equation 2.2)}$$

PV = present value
FV = future value
i = interest rate
n = the time period in question

This process of increasing the cost by the inflation rate and then discounting it with the interest rate is performed on all of the annual costs for the 65 year life span of the house in

question. The individual present values calculated show the user how much money would have to be put aside, at the specified interest rate, to have the amount of money needed in the year of the expense. Once this present value is found for each year, the 65 values can be added together to obtain the total amount of money needed to build and maintain the house over the next 65 years.

The next step is to annualize the cost of the house over the next 65 years using the total present value. The annualized cost "determines the equal payments on an annual basis" over the time period in question [Park, 1990: 65]. Basically, the annualized cost is an equivalent cash flow to make comparisons easier. It is not the actual amount spent, but an equal payment each year of the 65 year time period. The actual amount spent is represented by the inflated value previously calculated. The following equation is used to determine the annualized cost [Canada, 1996: Table 2-1]:

$$A := PV_{tot} \cdot \left[\frac{i \cdot (1+i)^n}{(1+i)^n - 1} \right] \qquad \text{(equation 2.3)}$$

A	= the Annualized cost
PV_{tot}	= the sum of true present value costs over 65 years
i	= the interest rate
n	= 65 years

The value A is the annualized cost of building a new house On-Base. This annualized new house cost can be compared to the annualized costs of housing a military family Off-Base and maintaining an existing house On-Base to determine the least cost option.

Maintaining Existing On-Base Housing

The economic analysis for maintaining an existing house On-Base is virtually the same as building a new house On-Base. The difference in the analysis of maintaining an existing house On-Base is that the demolition and construction costs will not be in year one, but will occur at the point at which the existing house is retired and a new house replaces it. The cost in year one will be a maintenance cost that will vary depending on the initial age of the house. The construction cost could occur at any point from year two to year 65.

The same concepts apply and the same equations are used that were discussed in the section dealing with building a new house On-Base. The cost for each year in the 65 year time period will be determined and then inflated by the inflation rate to the appropriate future value. That future value will then be discounted by the interest rate to determine the present value, and the annualized cost will be determined from the total of true present values. Comparing the annualized cost of maintaining this house to the annualized cost of building a new house and housing a military family Off-Base will determine which housing to use. If there are many different existing On-Base housing groups that have different ages and characteristics, each must be considered separately.

Housing Military Families Off-Base

This economic analysis is also very similar to the analysis described in building new On-Base housing. The cost for each year is the amount to be paid to the military family as compensation for living Off-Base (BAQ+VHA), with a demolition cost added in the first year when necessary. The yearly cost of BAQ&VHA is inflated using the recommended annual military pay increase of 3.0% [Fiscal Year 1997 Revised Inflation Guidance, 1997]. Once these

future values are determined they are discounted using equation 2.2. The present values are then totaled, and the annualized cost of paying a military family to live Off-Base is calculated using equation 2.3. The annualized cost can then be compared to the other two options in order to determine the least cost housing option.

2.4.2 Decision Analysis

Robert Clemen describes the purpose of decision analysis as "to help a decision maker think systematically about complex problems and to improve the quality of the resulting decisions." [Clemen, 1996: 10]. The complex problem faced in this thesis is the decision of what combination of housing options should be used for an Air Force Installation. Decision analysis helps to find the best solution to the problem taking all constraints and conditions into account. In order to improve the quality of the decision made, it is necessary that the decision maker understand the process used to make the decision. Following a logical flow through the decision analysis process the best decision can be made and all of the variables analyzed. The following figure is taken from Clemen's book Making Hard Decisions, and illustrates the decision analysis process.

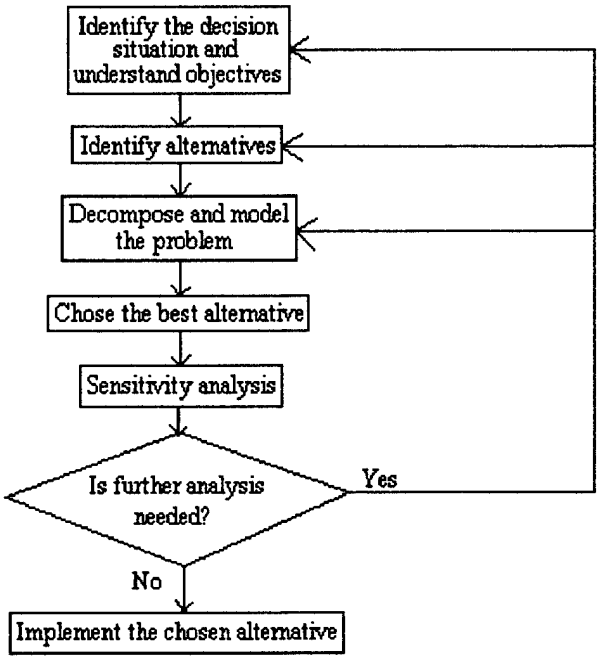

Figure 2.1 A Decision Analysis Process Flow

Fundamental Objective:

The first step in making a decision is to understand the values and objectives of the decision maker and to know what the situation is in which the decision must be made. In this analysis of military family housing, the objective is to minimize the cost of housing military families while operating under the constraint that all families must be housed adequately according to the guidelines found in the HMA of affordability, location, quality, and size [Edwards HMA, 1994]. Further, the constraint of availability must be considered when compiling the least cost combination; once the availability of one option has been eliminated, the decision maker must resort to the remaining options.

Alternatives:

In a decision process there are alternatives that must be identified, otherwise there would be no decision. The alternatives available to house a military family are building new On-Base

housing, using existing On-Base housing, and paying the military family to live Off-Base. A combination of these three options will be the least cost combination.

Decomposition and Modeling:

The step titled "decomposition of the model and problem" is the key to the decision analysis. The approach is to "divide and conquer" the problem. Decomposing the problem helps the decision maker to understand the structure and relationships of a difficult problem [Clemen, 1996: 7]. When determining the optimal combination of housing, the decomposition of the model and problem can be identified as the results of the economical evaluation of each option. The results will identify the cost of each option and the one with the least cost can be chosen. This least cost option is the best economically over the next 65 years. Operating under the given constraints, this process will result in the a combination of housing that is the best alternative.

Sensitivity Analysis:

Once this best alternative is chosen, a sensitivity analysis can be performed to allow the question of "what if" to be answered. What if a slight change was made to the variables, would it make a difference in the decision? All of the variables are held constant except the one being analyzed. The cost of the option is then calculated when the variable analyzed is varied over a specific range. The change in the cost of that option tells the decision maker how a change in the variable would effect the cost. Points at which a decision change would occur are identified when the cost of the option increases above the cost of one of the other alternatives.

The decision analysis approach to a difficult problem can break down the problem into less complicated sections to deal with one at a time. These individual sections can be analyzed until the decision maker is certain that the best alternative has been chosen [Clemen, 1996: 6].

2.4.3 Combining Decision Analysis and Economic Analysis

By using a combined decision analysis and economic analysis approach to the problem, the Air Force can determine the optimal combination of housing for any installation. The economic analysis uses accepted economic equations to calculate the cost of housing a single military family in one of the three options: 1) an existing house On-Base, 2) a new house On-Base, and 3) paying that family VHA and BAQ to live Off-Base. After these costs have been determined, decision analysis helps the decision maker to place the military family in the lowest cost option adhering to certain constraints such as available Off-Base housing, available On-Base housing, mission essential On-Base personnel, etc. Once all of the military families have been placed into their lowest cost option, the optimum combination of On and Off-Base housing is evident. Further analysis can be performed on the optimum choice using sensitivity analysis to determine if and when a decision change would occur. The sensitivity analysis can serve as a check on any estimates that are used in the decision process. For example, if there is a decision change when a variable is analyzed, the decision maker is informed that this is a very influential variable and that there is not much room for error. These two types of analyses used together allow the best option to be chosen and adequately evaluated.

2.5 Information Needed to Determine the Cost of Each Alternative

When determining the combination of MFH to provide on an Air Force Installation, the economic conditions of the area surrounding the installation must be considered. There are many variables that must go into the calculations of determining the least cost combination of housing which differ with each housing option. The purpose of this section is to identify all of the

variables needed in the calculation of each alternative's cost. By presenting each alternative individually, the respective variables can be identified.

Building New On-Base Housing

The information needed to determine the cost of building new On-Base housing is:

1) Demolition Cost (if applicable)
2) Construction Cost of a new house
3) Revitalization Costs
4) Annual Maintenance Cost
5) Inflation rate
6) Interest rate
7) Area Cost Factor
8) Housing Factor

The first cost associated to this housing option is the demolition cost of the existing housing. In order to compare the option of building new housing to the option of maintaining that housing, consideration must be given to the demolition of the existing housing. The average demolition cost Air Force wide is estimated at $8,000 [Jameson; 1997]. This cost will vary depending of the location of the installation and is adjusted by the area cost factor.

The second variable is the construction cost of a new house On-Base. When building new housing, the construction cost will occur in year one. For the remaining life of the house, there will be some type of maintenance cost each year. According to the Fiscal Year 98/99 Family Housing Investment Program, the average construction cost of a new house On-Base is projected to be $139,000. This is an expected average cost of all types of homes built throughout the Air Force. Homes built for different military pay grades will be differentiated by the square footage requirements. This difference is accounted for with the housing factor.

The third variable is the revitalization costs. Under Air Force Policy, On-Base Housing should undergo revitalizations at the 25 and 45 year points of the housing's life span to bring the house back to the quality of a new home. After 65 years, the old housing should be replaced with new housing. The average cost of revitalizing a house On-Base back to the quality of a new home is projected to be $102,000 by the Fiscal Year 98/99 Family Housing Investment Program. The revitalization is performed to extend the life of the house 20 years from the time of revitalization. The revitalization allows for the entire house to be updated with new systems and appliances to ensure that the house is safe and that the systems are efficient [Family Housing FY 98/99 Investment Program, 1997]. Like the Construction cost, the Revitalization cost will differ depending on the square footage of the house. This difference in cost associated with houses built for different pay grades will be accounted for using the housing factor.

Once a house is built On-Base, it must be maintained. The average maintenance cost of a house On-Base was calculated by dividing the total maintenance cost of AFMC housing by the total number of AFMC houses. The numbers for this calculation were taken from the "Military Family Housing O&M (7045) Fiscal Year 1998 Financial Plan." The total cost of AFMC housing reported in this financial plan was $45,138,000 for fiscal year 1998, and the total number of houses under AFMC was reported to be 14,581 units. The average annual cost was:

$$\$45,138,000 / 14,581 \text{ units} = \$3,096 \text{ per unit}$$

This value is the value used in the development of the maintenance cost curve. AFMC also expects a 10% increase in maintenance costs every 5 years due to the aging of the house [Jameson, 1997]. This would therefore be a 2% increase in maintenance cost every year in excess

of inflation. The figure below is a graph of the maintenance costs over the lifetime of a house. The 2% increase in costs due to the aging of the house can be seen as the costs rise. Notice that inflation has not been applied to this graph, and that the costs in years 2, 26, and 46 are all the same amount because the revitalizations bring the house back to the quality of a new home. The suspected 10% rise in costs every 5 years due to real cost increases is expected to be offset by better quality materials and new technology in the revitalizations. The resulting maintenance cost curve without the construction and revitalization costs applied would look like this:

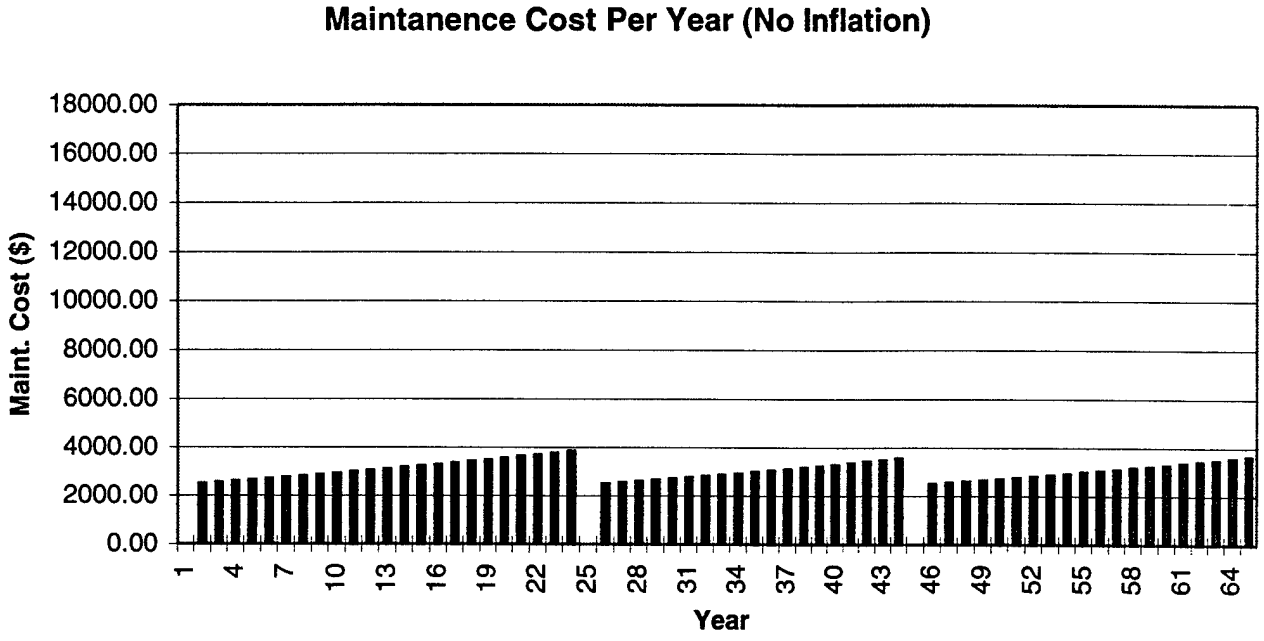

Figure 2.2 Maintenance Costs of a House (No Inflation)

In order to form the curve above, the average annual maintenance cost, calculated to be $3,096, was assumed to apply to the 13th year of a house's life. The 2% expected annual increase in maintenance cost was then applied until the revitalization in year 25. To account for the cost of maintenance from years 2 to 12, 2% of the maintenance cost was subtracted out from year 13

to 2. The resulting curve averages a maintenance cost of $3,096 with a 2% increase in cost from year 2 to 24.

The graph above does not include construction and revitalization costs; however, the maintenance costs can be seen over the entire life of the house. The construction cost would be in year 1, and the revitalization costs would be in years 25 and 45. There would be no maintenance cost in these years because the construction or revitalization would encompass the maintenance cost for that year. Inflation has not been included on this graph to reflect consistent maintenance costs after each revitalization.

The fifth and sixth variables are the inflation and interest rates. The inflation and interest rates are necessary in the economic calculations to account for the time value of money. Inflation will cause the costs to increase over time while the interest or "discount" rate reflects the present value of a future expense. The inflation and interest rates used in this study are 2.5% and 6.3% respectively, and are taken from the Fiscal Year 1997 Revised Inflation Guidance. To see the effect of inflation, Figure 2.2 can be viewed again with an inflation rate of 2.5% applied to the maintenance cost.

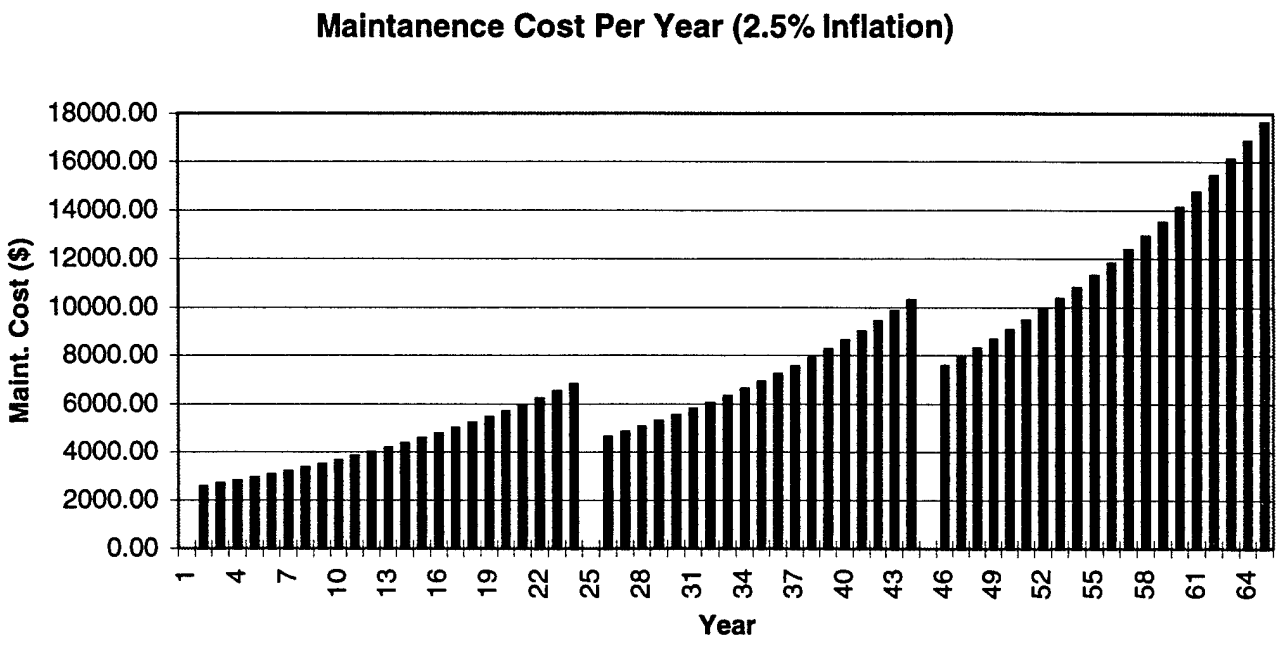

Figure 2.3 Maintenance Costs of a House (Inflation 2.5%)

Now the effect of inflation can be seen on the graph of the maintenance costs. Even though the revitalizations bring the house back to the quality of a new home, inflation causes the maintenance cost of a newly revitalized house to increase. For example, without inflation the maintenance cost in years 2, 26, and 46 would all be the same; however, inflation causes the costs to increase over time. In order to show the entire graph of costs over the lifetime of a house, the construction and revitalization costs have been included in the maintenance cost graph below. Inflation has not been applied to reflect the consistency in revitalization costs.

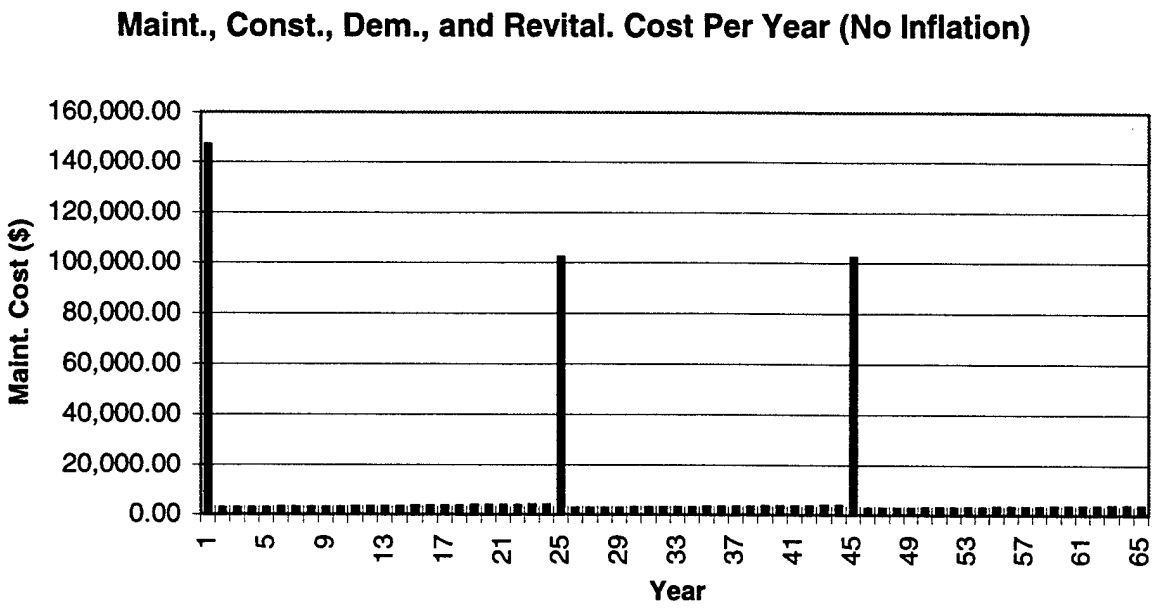

Figure 2.4 Maint., Const., Dem., and Revital. Costs of a House (No Inflation)

The construction and revitalization costs can be seen very clearly on this graph. If inflation were applied, the same type of increase in the costs would occur over time as was seen in the maintenance cost curve above.

The Area Cost Factor (ACF) should not be used if the local costs are known for the installation. However, when Air Force averages are used the ACF adjusts the cost of Demolition, Construction, Revitalizations, and Maintenance to reflect the increase or decrease in costs related to the location of the installation under study. "The area cost factors are based on a bi-annual survey of local costs for a market basket of labor crafts, construction materials, and equipment items. These labor, materials, and equipment items are a representative of the types of products and services used to construct most military facilities." These area cost factors are provided in Appendix A [Guidance for DOD Facility Construction for FY 1999 and 2000, 1997].

The housing factor is a factor used to distinguish between the cost of building military family housing for different military ranks. When building or maintaining a house On-Base, the costs differ depending on the size of the house. There are different square footage requirements for different military ranks, therefore the appropriate price can be accounted for using this factor. The factor is based on the square footage required for each rank. The maximum net floor areas for the military ranks are:

O6-UP-	1,900 SF
O4-O5-	1,475 SF
O1-O3-	1,325 SF
E7-E9-	1,325 SF
E4-E6-	1,262.5 SF
E1-E3-	1,262.5 SF

Using these floor areas, a ratio can be determined to distinguish between the houses built for the different military ranks. The average maximum square footage is 1,425 SF. The resulting housing factors for each category of rank are:

O6-UP -	1.33
O4-O5 -	1.04
O1-O3 -	0.93
E7-E9 -	0.93
E4-E6 -	0.88
E1-E3 -	0.88

Using all eight of the factors that have been discussed in this section, an accurate estimate of the cost of building new On-Base housing can be calculated. This cost can be compared to the cost of each of the other two options.

Maintaining Existing On-Base Housing

The information needed to determine the cost of maintaining On-Base housing is the same as building new housing with the addition of the Age of the existing housing. The information needed is:

1) Demolition Cost
2) Construction Cost of a new house
3) Revitalization Costs
4) Annual Maintenance Cost
5) Inflation rate
6) Interest rate
7) Area Cost Factor
8) Housing Factor
9) Age of the Existing Housing

Calculating the cost of this option is very similar to the option of building a new house On-Base. The only difference is that the yearly costs do not start with a construction cost in the first year. The same type of maintenance curve can be built for this option to show the costs in each of the next 65 years. For example, if the housing is 20 years old, then the maintenance cost must start at the cost for a 20 year old house rather than a new house like the graphs above. Figure 2.5 reflects the maintenance cost curve for this scenario:

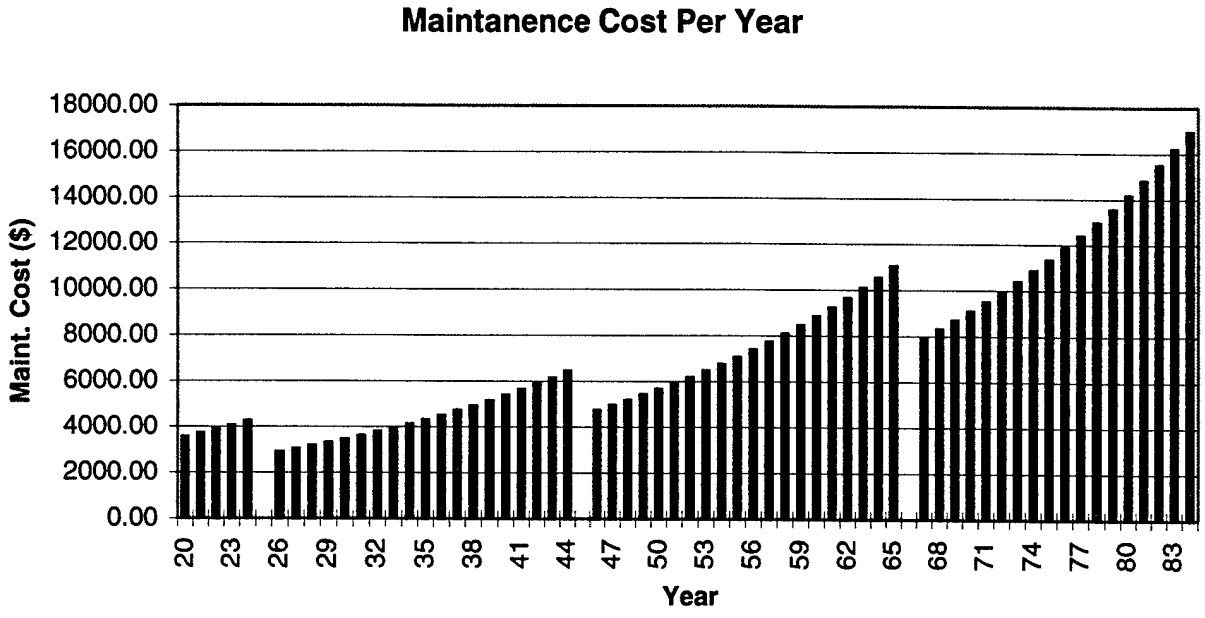

Figure 2.5 Maintenance Cost Curve of a 20 year old House (Inflation 2.5%)

Notice that the first year shown on the graph above is year 20, the age of the house. The revitalizations still occur when the house is 25 and 45 years old, in order to keep the house updated. Once the house is retired at 65 years old, a new house is built to replace the retired home. So, actually the case of a new house is just one of the 65 possibilities of the maintenance cost curve for an existing house.

Housing Military Families Off-Base

The third option of housing is to pay a military family to live Off-Base. The information is needed in determining the cost of this option:

1) Demolition Cost (if applicable)
2) Area Cost Factor
3) the amount of reimbursement for the family to live Off-Base (BAQ+VHA)
4) the percentage increase in the housing allowance per year
5) Interest Rate

(Inflation is not needed because the annual percentage increase in housing allowance is used by the military to account for inflation)

In order to compare the cost of this option to maintaining existing housing, consideration must be given to the demolition cost of the existing housing. Like the option of building new On-Base housing, the demolition cost is not used in the cases where the demolition of a house is not necessary.

The next variable is the reimbursement given to the family in question to live Off-Base. This reimbursement is the amount of BAQ and VHA given to the military sponsor. The BAQ+VHA rate will change depending on the rank and dependent status of the individual military member. The VHA rate will also change depending on the location of the Air Force Installation. Once this amount is known, the expected increase in this variable needs to be determined for the 65 year time period.

The percentage increase in BAQ and VHA per year is estimated at 3.0%{DoD, 1997]. The 3.0% increase per year is the value to be used when estimating annual pay raise increases over more than 8 years [DoD, 1997].

The information identified in this section will allow the cost of each option to be determined. These costs can be compared to find the optimal housing choice for an Air Force family. However, when applying this procedure at an actual base, there are other important variables that must be considered. These variables do not effect the calculation of the cost of each option, but they may place constraints on which options may be used. These other constraints include:

1) Number of Mission Essential Personnel who must live On-Base
2) Available On-Base Housing
3) Available Off-Base Housing
4) Number of Military Families at the Installation

Once the Mission Essential Personnel who must live On-Base have been accounted for, the decision maker can chose the least cost option to house the remaining military families until reaching one of the other constraints. Military families can only be housed in existing On-Base housing until the units are full. The remaining other families must be housed Off-Base or new housing must be built to account for them. Also, military families can only be housed Off-Base until the available Off-Base housing is diminished. Using the factors above, the military families can be housed in the least cost option without exceeding a constraint.

2.6 Where the Data can be Found

The average maintenance cost has been determined as an AFMC average from data provided by AFMC housing programmers. This average is assumed to hold true for installations under any MAJCOM; however, individual MAJCOMs or installations can substitute their average maintenance costs if desired. The demolition, construction and revitalization costs are Air Force averages. Applying the area cost factors to these values will tailor the cost to the installation that is analyzed.

Demolition Cost = $8,000

Construction Cost of a new House = $139,000

Revitalization Cost = $102,000

Average Yearly Maintenance Cost = $3,096

Area Cost Factor = Appendix A

The inflation rate, interest rate, and annual increase in BAQ and VHA used for government calculations are taken from the FY 1997 Revised Inflation Guidance. They are estimated to be:

Inflation Rate = 2.5%

Nominal Interest Rate = 6.3%

Annual Increase in BAQ and VHA = 3.0%

BAQ+VHA rate = Base Military Pay Office

Age of Existing On-Base Housing = Base Real Property Records

Housing Factor

O6-UP -	1.33
O4-O5 -	1.04
O1-O3 -	0.93
E7-E9 -	0.93
E4-E6 -	0.88
E1-E3 -	0.88

Amount of Existing On-Base Housing = Base Housing Off.

Available Off-Base Housing = HMA

Number of Military Families at the Installation = HMA

Number of Mission Essential Personnel who must live On-Base = HMA

2.7 Summary

Housing military families is one of many services that the Air Force provides to its members in order to allow them to focus on their primary jobs. Adequate housing can be

provided for an Air Force family utilizing one of three options. These options are 1) build new On-Base housing, 2) use the existing On-Base Housing, or 3) pay a housing allowance to the family to find housing Off-Base. While any of these three options would adequately house the family, each has a different cost associated to it. Determining the economically optimal combination of housing could help the Air Force in its effort to decrease spending. The economically optimal combination of housing for an Air Force Installation is some combination of the three options listed above. The cost of each option can be determined using the economic principles presented in this chapter. Using the calculated costs and the limiting constraints of the area in which the Air Force Installation is located, the economically optimal combination of housing military families can be determined.

The current Air Force Strategy dealing with Military Family Housing is to utilize the existing housing On-Base, and look to the local community to house the remaining families. The only way that the Air Force will currently build new housing is if the local community can not provide for the additional military families. This current strategy may or may not provide the least cost combination. Using the economic and decision analysis principles described in this chapter, the economically optimal combination of housing can be determined for any Air Force Installation. Armed with this information, an informed decision can be made of what combination of housing to use at any Air Force Installation.

III. Methodology

3.1 Introduction

In order to determine the least cost combination of Housing for an Air Force Installation, a method is needed that will take economic analysis and decision analysis into consideration. Decision Analysis allows the decision maker to evaluate many different possible solutions to a problem and compare the respective outcomes. Using a spreadsheet on Microsoft Excel®, an economic tool was built that will allow the optimal combination of housing to be identified. The model developed can be broken down into two levels, the individual model (which is used for a particular set of military ranks) and the overall model (which is the combination of all of the individual models). By changing the inputs, the optimal combination of housing for any installation can be determined.

This chapter will guide the user through the methodology used in determining the least cost combination of housing. The first step is to define the optimal decision. Next, the decision process that will lead to the optimal decision can be explained. Once the decision process is explained, the model development in Microsoft Excel® will be discussed. From that point, the difference in the individual model and the overall complete model can be understood. A final discussion of the model assumptions will complete this chapter on methodology.

3.2 The Optimal Combination of Housing

The Optimal Combination of Housing for this analysis is defined as the Lowest Annualized Cost Combination of Housing for the entire installation. This model was built to perform an economic analysis of the local area around an Air Force Installation, and to provide the user with the combination of housing that is least expensive. The least cost combination of housing will be

a combination of the three alternatives that have been previously discussed. The three alternatives are:

1) Build new housing On-Base
2) Utilize existing housing On-Base
3) Require that the military families live Off-Base by providing a housing allowance

Because of the different housing requirements, the pay grades at an installation have been broken down into several categories. In this analysis, the military families at the installation under study have been divided into six categories. The cost of building and revitalizing houses intended for different ranks, as well as the amount of pay given to military families to live Off-Base varies. By dividing the families at the installation into six categories, a more accurate cost analysis can be performed on the options available for housing each group. The six categories are:

1) E1-E3
2) E4-E6
3) E7-E9
4) O1-O3
5) O4-O5
6) O6-UP

The decision of which housing option to use will differ depending on the costs associated with the respective options for each category. Once the least cost combination of housing is determined for the six categories above, all six combinations can be combined to form the overall optimal combination for the entire installation.

3.3 Decision Process

The decision process used in this model steps the decision maker through the calculations to arrive at the overall decision. This process can be portrayed in Figure 3.1 below. The user input is location specific.

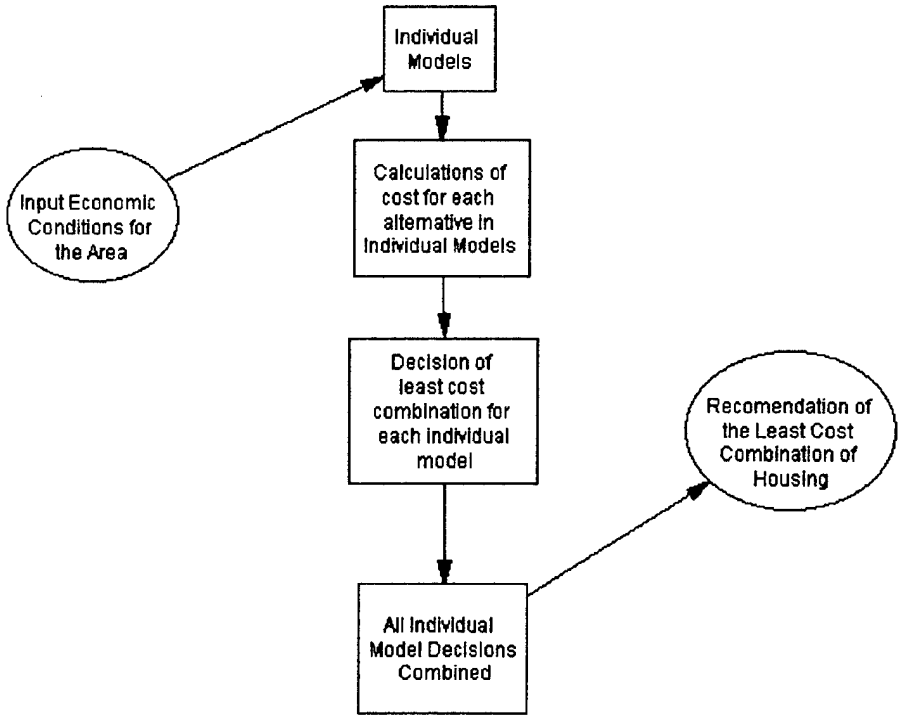

Figure 3.1 Decision Process

The overall model is made up of the combination of six individual models. Each one of the six individual models corresponds to one of the six rank categories described in the previous section. The individual model will determine the least cost combination of housing for the military families that are in its category. Utilizing six individual models accounts for the different values of variables and constraints associated with each particular rank category.

The flow of the model starts with the input of data for all of the individual models. An example of the differences from one model to another may be the amount of VHA and BAQ given to the different ranks, or the number of military families at the location that fall in the different rank categories. Once this data has been put into the model, the least cost combination is identified for each individual model and compiled into an overall final decision. This final decision is reported to the user of the model as least cost combination of housing for the installation. The final decision also reports the total annual cost of housing under both the recommended combination and the current Air Force Strategy. This allows the decision maker to observe the potential savings from using the economically optimal combination.

3.4 Model Development

There will be two types of data input for the model. The first type of data is global to the overall model, and will be the same for all six individual models. This global data consists of variables such as the interest rate and area cost factor which are not dependent on military rank. The second type of data is local data. The value used for a local variable will change in each of the six individual models. Examples of local data include the number of military families at the installation and housing factors. There are not the same number of military families at the installation for the E1-E3 rank category as there are for the O6-UP rank category, therefore the value used for that variable will be different for each individual model. The housing factors will differ from 0.88 for the E1-E3 rank category to 1.33 for the O6-UP category. The following is a complete list of the variables which need to be input into the model:

The Global Variables:

- Area Cost Factor
- Inflation Rate
- Interest Rate
- Yearly Increase in VHA & BAQ

The Local Variables: (Installation and/or Housing Group Dependent)

- Amount of VHA & BAQ
- Age of the Existing Housing
- Years since last Revitalization
- Years until next Revitalization
- Amount of Existing On-Base Houses
- Number Military Families at the Base
- Available Off-Base Housing
- Number of Mission Essential Military Families who must live On-Base
- Demolition Cost of an Existing House
- Construction Cost of a new House
- Revitalization Cost of a House
- Average Annual Maintenance Cost
- Housing Factor

A brief description of each input variable is listed below.

Area Cost Factor - The area cost factor will change with the area that is being studied. The area cost factor is used to account for the difference in construction and labor costs of the

different parts of the country in which the Air Force Installations are found. This factor can be taken from Appendix A. This factor will only be used in conjunction with Air Force averages. It will not be used when the local costs are known.

Inflation rate - The inflation rate is a measure of the decline of the purchasing power of the dollar. The inflation rate shows that it will cost more to build or maintain a house in future years than it does in the present year. This can be input by the user, but the 1997 Revised Inflation Guidance recommended rate is 2.5%.

Interest rate - The interest rate shows the time value of money, which has earning power that can be achieved by investing. This can be input by the user, but the 1997 Revised Inflation Guidance recommended rate is 6.3%.

Yearly Increase in VHA & BAQ - The yearly increase in VHA & BAQ is a value that will affect all of the individual models calculations. This can be input by the user, but the 1997 Revised Inflation Guidance recommended rate is 3.0%.

Amount of VHA & BAQ - This is the amount of pay that a military members receives for living off base. This value changes depending on the military member's rank, dependent status, and the location of the installation. When determining this value for an individual model, a weighted average is found which covers all grades included in that individual model.

Age of the Existing Housing - This is the age of the housing that is currently used to house the military families that fall under an individual model's grade category. There may be several different groups of housing in a rank category; therefore, this variable may be used several times in one individual model.

Amount of Existing On-Base Houses - This is the number of units available to house the military members that fall into an individual model's category. This variable will correspond to

the Age of the Existing Housing variable. There may be several different groups of housing in a rank category; therefore, this variable may be used several times in one individual model.

Years since last Revitalization - This variable also corresponds to the Age of the Existing Housing. When there are several groups of housing, there may be several respective times since the last revitalization of each group. This variable allows the user to identify how long it has been since the last revitalization. If there has never been a revitalization performed on the house then the age of the house should be entered into this variable. Using a zero in this variable will default it to the standard Air Policy illustrated by the maintenance cost curve in chapter 2.

Years until next Revitalization - This variable also corresponds to the Age of the Existing Housing. When there are several groups of housing, there may be several respective times until the next revitalization of each group. This variable allows the user to reflect delays in the revitalization of a house due to financial constraints. To default to standard Air Force Policy, again a zero should be entered into this variable. By defaulting to standard Air Force Policy, the revitailzations will occur in years 25 and 45 of the house's life, and the housing will be replaced in the 66^{th} year.

Number of Military Families at the Base - This is the number of military families that fall under each individual rank category that are assigned to the installation being studied. The assigned number of families is used in this evaluation instead of the authorized number to account for actual costs incurred by the installation. Given the trend in downsizing the military, it is important that the housing need is not overstated by using the authorized number of families.

Available Off-Base Housing - This can be found in the most recent Housing Market Analysis. It is the number of units available to an individual model's ranks off base. The categories used in the HMA are the same as the categories used in this model.

Number of Mission Essential Military Families who must live On-Base - Each individual rank category may have a certain number of personnel who have jobs that require them to live On-Base. This variable ensures that at least that minimum amount of housing will be available On-Base.

Demolition Cost of Existing Housing - This is the cost of tearing down the existing housing. The recommended Air Force average is $8,000. The demolition cost is subject to variability because of special cases which might be present. When there are environmental considerations such as asbestos removal or lead paint removal, this cost can increase considerably. The area cost factor is used to adjust this value to apply to the local area. If the costs for the local area are known or if they are included in the new construction costs, then the area cost factor should be used as a value of one.

Construction Cost of a New House - This is a variable that the user has the ability to change if needed. If the user does not want to change this value, the Air Force average of $139,000 should be used. The area cost factor also adjusts this variable, so if the local costs are used adjust the area cost factor to one.

Revitalization Cost of a House - Like the Construction Cost, this is a variable the user has the ability to change. The value to be used is the Air Force average of $102,000. This Revitalization is designed to bring the house back to the original standards of a new home. The area cost factor is used to adjust this variable, so if the local costs are used adjust the area cost factor to one.

Average Annual Maintenance Cost - The average annual maintenance cost of $3,096 is assumed to hold true Air Force wide; however, it can be changed if the user desires. The $3,096 represents the cost of maintenance on an averaged age house. The model adjusts this value to

apply to older and younger homes by the annual 2% expected increase in maintenance costs. The Area Cost Factor is also used to adjust this Air Force average to apply to the installation. If local costs are used, the ACF should be adjusted to one.

Housing Factor - The housing factor is used to differentiate between the cost of housing for the different categories of ranks represented by the individual models. The housing factor is applied to the construction and revitalization costs to account for the different size of housing required for the different ranks. The recommended housing factors are:

O6+ -	1.33
O4-O5 -	1.04
O1-O3 -	0.93
E7-E9 -	0.93
E4-E6 -	0.88
E1-E3 -	0.88

These housing factors were determined by a ratio of the square footage required for each category to the average square footage of On-Base Military Family Housing.

Once all of this data has been obtained by the user of the model, the data can be input into the proper cells of the Microsoft Excel® Spreadsheet. The Excel spreadsheet will then calculate the optimal combination of housing from the costs of each alternative. See Appendix B to reference the user's manual for this model.

3.4.1 Individual Decision Model.

The individual models allow the user to determine what the least cost combination of housing is for a particular category of ranks (i.e. O1-O3). Each of the categories may have several groups of On-Base housing designated for its use. These groups of housing could all have different ages and times since their last revitalization. Because of these differences, the cost of

maintaining each group of housing will be different. As a result, the recommendation may be that some of these housing groups should be used and others abandoned. As written, the spreadsheet will allow up to eight groups of housing for the 3 enlisted rank categories, and will allow up to four different groups of housing for the 3 officer rank categories.

A second way to use the individual model is as an experimental way to test the sensitivity of variables in a particular rank category. For example, the individual model could be used to check for BAQ & VHA rate effects on the housing decision for that particular category. Using the individual model on its own allows the user to quickly investigate the affects of small changes to the input of the model. A portion of the individual model for the category E1-E3 is shown in Figure 3.2 below (The data in Figure 3.2 is contrived data used to show an example). The only difference in what is shown and the actual spreadsheet is that only 3 groups of housing are shown. The actual spreadsheet continues to the right for 8 separate groups of housing for Edwards AFB. Another base may have only 2 or 3 distinct groups of housing for E1-E3.

Variables that effect the individual models:	E1-E3		
Construction Cost of New =	139000.00	**BAQ+VHA =**	460
Revitalization Cost =	102000.00	**Housing Factor =**	0.88
Average Maintenance Cost =	3096		
Demolition Cost =	6000		
Number of Families =	110	Current Strategy On-Base Cost =	$1,967,200.61
Number of Mission Essential Families =	0	Current Strategy Off-Base Cost =	$0.00
Available Off-Base Housing =	300	Current Strategy E1-E3 Cost =	$1,967,200.61
Up to EIGHT different groups of Housing:	**1**	**2**	**3**
Age of the Existing Housing =	53	39	47
Years since last Revitalization =	10	39	15
Next Revitalization Due =	11	0	6
Years until next Revitalization =	0	0	0
Available On-Base Housing =	75	20	25
On-Base Housing to be Used =	75	0	25
	Maintain	House Off	Maintain
Annual Cost Per House =	15499.54	18514.58	17377.75
Total =	$1,162,465.26	$0.00	$434,443.72
Off-Base & Demolition Cost of Unused Housing :	$143,603.58	Housed Off-Base =	10
On-Base Cost =	$1,596,908.98	Housed On-Base =	100
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For E1-E3 =	$1,740,512.56		110

Figure 3.2 The Individual Decision Model

In the spreadsheet shown in Figure 3.2, the On-Base cost is calculated by summing all of the "Totals" under the housing groups. The "Off-Base and Demolition Costs of Unused Housing" is determined by adding the cost of demolishing the 20 unused houses to the annualized cost of housing 20 families Off-Base. There are no new houses built; therefore, the "Cost Building New" is zero. The total cost for the optimal combination of this category is shown in the cell beside "Total Cost for E1-E3." This total is less than the Current Strategy total, which is found by utilizing all of the On-Base houses. The difference in this instance is $226,688.05, which represents the annualized savings to the installation if the recommended combination is used.

The spreadsheet allows the user of the model to change any of the input variables and observe how the cost of each group of housing, as well as the total cost for this category will

change. The input variables are identified by the colored cells (blue, green, and yellow). The user can also observe that the economically optimal combination of housing is identified with the listing of how many families to house in existing On-Base housing, how many families to house Off-Base, and how many new houses to build. The cost of each of these options is listed as well.

One variable that requires some extra attention is the "Years until next Revitalization." The spreadsheet in Figure 3.2 shows that the cell above this variable is "Next Revitalization Due." The "Next Revitalization Due" cell informs the user of the model how many years there are until a revitalization is due on the housing group in question. If the value is 11, then a revitalization is due on that group of housing in 11 years. The variable "Years until next Revitalization" defaults to the recommended number of years from standard Air Force Policy that is shown in "Next Revitalization Due" when a 0 is input into the cell. However, if the user would want to delay the revitalization, a different number could be used. For example, if the user wanted to delay the revitalization an extra year because of budget constraints, a 12 could be entered into the cell holding the variable "Years until Next Revitalization." By entering a 12 into that cell, the revitalization cost is delayed for one year. The cost associated to the year that the revitalization was due (11 years from the present) is determined by continuing the increase in maintenance cost by 2% per year. It is strongly encouraged that the recommended schedule be kept in order to keep the housing up to date, but the "Years until Next Revitalization" variable allows the user to delay the revitalizations when necessary.

3.4.2 The Overall Decision Model.

The Overall Decision Model combines all of the results of the individual decision models and reports this to the user as the final decision. This Overall model is a combination of all of

the individual models in the spreadsheet. The Overall Model will report the optimal combination's overall annualized cost of housing, along with the cost of housing using the current Air Force Strategy. The Overall Model, covering the first two categories which are: E1-E3 and E4-E6, is shown in Figure 3.3.

The savings that can be achieved by using the recommended combination of housing is the difference between the "Cost of Optimal Combination" and "Current Strategy Cost". These two costs can be found on the right side of the top of the Figure 3.3 spreadsheet. For the scenario shown, the potential annualized savings of the installation is over $1.3 million.

$$\$33,442,699.65 - \$32,124,819.00 = \$1,317,880.65$$

The savings above is for all six categories combined, and not just for the two rank categories shown. The determination of each individual rank category is explained in the previous section titled "Individual Decision Model".

INPUT FOR THE MODEL		Cost of Optimal Comb. =	$32,124,819.00
Variables that Effect the entire model:		Current Strategy Cost =	$33,442,699.65
Area Cost Factor =	1.21		
Interest rate =	0.063		
Inflation rate =	0.025		
Military Yearly Increase in BAQ&VHA =	0.03		
Variables that effect the individual models:	E1-E3		
Construction Cost of New =	139000.00	**BAQ+VHA =**	460
Revitalization Cost =	102000.00	**Housing Factor =**	0.68
Average Maintenance Cost =	3096		
Demolition Cost =	8000		
Number of Families =	110	Current Strategy On-Base Cost =	$1,967,200.61
Number of Mission Essential Families =	0	Current Strategy Off-Base Cost =	$0.00
Available Off-Base Housing =	212	Current Strategy E1-E3 Cost =	$1,967,200.61
Up to EIGHT different groups of Housing:	**1**	**2**	**3**
Age of the Existing Housing =	53	39	47
Years since last Revitalization =	10	39	15
Next Revitalization Due =	11	0	6
Years until next Revitalization =	0	0	0
Available On-Base Housing =	75	20	25
On-Base Housing to be Used =	75	0	25
	Maintain	House Off	Maintain
Annual Cost Per House =	15499.54	18514.58	17377.75
Total =	$1,162,465.26	$0.00	$434,443.72
Off-Base & Demolition Cost of Unused Housing =	$143,603.58	Housed Off-Base =	10
On-Base Cost =	$1,596,908.98	Housed On-Base =	100
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For E1-E3 =	$1,740,512.56		110
Variables that effect the individual models:	E4-E6		
Construction Cost of New =	139000.00	**BAQ+VHA =**	611
Revitalization Cost =	102000.00	**Housing Factor =**	0.68
Average Maintenance Cost =	3096		
Demolition Cost =	8000		
Number of Families =	1000	Current Strategy On-Base Cost =	$17,156,573.92
Number of Mission Essential Families =	0	Current Strategy Off-Base Cost =	$0.00
Available Off-Base Housing =	475	Current Strategy E4-E6 Cost =	$17,156,573.92
Up to EIGHT different groups of Housing:	**1**	**2**	**3**
Age of the Existing Housing =	53	39	47
Years since last Revitalization =	10	39	15
Next Revitalization Due =	11	0	6
Years until next Revitalization =	0	0	0
Available On-Base Housing =	375	425	200
On-Base Housing to be Used =	375	425	0
	Maintain	Maintain	House Off
Annual Cost Per House =	15499.54	18514.58	17377.75
Total =	$5,812,326.32	$7,868,697.60	$0.00
Off-Base & Demolition Cost of Unused Housing =	$3,074,504.78	Housed Off-Base =	200
On-Base Cost =	$13,681,023.92	Housed On-Base =	800
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For E4-E6 =	$16,755,528.70		1000

Figure 3.3 One Third of the Overall Decision Model

Once all of the data is input into the model, an overall cost of housing at the installation in question is calculated at the top of the spreadsheet. This is an annualized cost of housing for the next 65 years. That total cost of the economically optimal combination can be compared to the total annualized cost of housing under the current Air Force Strategy.

It is also important to notice that under each group of housing for a particular rank category, there is a recommendation given which will be one of three variations:

1) **Maintain** - this recommendation tells the user that the least cost option for this particular group of housing is to maintain the existing housing.
2) **Build New** - this recommendation tells the user that this particular group of housing should not be maintained, and that the least cost option is to build new housing for this rank category.
3) **House Off** - This recommendation tells the user that it less expensive to house the military families in this category Off-Base than it is to maintain this group of housing or Build New.

This recommendation immediately informs the user of which groups of housing should be maintained and which groups should be abandoned. When housing is used to satisfy the constraints of available Off-Base housing and Mission Essential On-Base personnel, the recommendation may say "House Off" but the "On-Base Housing to be Used" cell will show the constrained number of houses that must be used. A user's guide of the Microsoft Excel® Spreadsheet is contained in Appendix B.

Once the overall decision is known, an analysis of the variables can be performed to determine how sensitive the variables are to change. This sensitivity analysis can be performed using any group of housing to determine if the decision to use that group would change when a

variable was changed. This allows the user to determine which variables have the most influence on the decision to use that particular group of housing.

To perform a sensitivity analysis on a particular variable, the cost of the least expensive housing option is calculated while varying a variable over a set range. These costs can then be graphed to observe how the cost of housing changes with the variations of the variable. A decision change would occur when the cost of the housing option that was originally lowest rises above the cost of one of the other options of housing. For example, if there was a decision recommended to house military families Off-Base, the cost of housing those families Off-Base would have been the least expensive option compared to building new or maintaining the existing housing. All variables could then be held constant except the one on which the sensitivity analysis is performed. The cost of all three housing options are then calculated as the variable is repeatedly changed. A graph of the results of the least expensive housing option's cost would show how the costs change as the variable changes. A decision change would occur at the point that the cost of housing the military family Off-Base was greater than the cost of one of the other two options. An example of the graph formed in this type of sensitivity analysis is shown below in Figure 3.4:

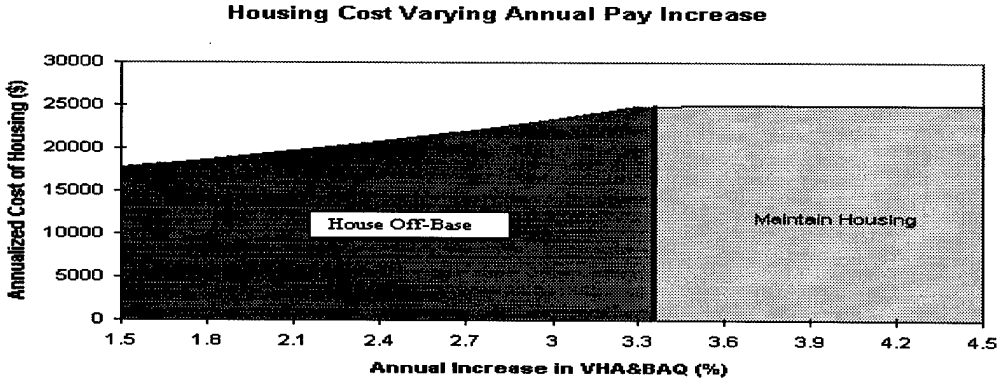

Figure 3.4 Sensitivity Analysis Example

In the example graph above, it is important to realize that every variable is held constant except the annual increase in VHA & BAQ. The annual increase in VHA & BAQ is shown on the x-axis and varies from 1.5% to 4.5%. The y-axis shows the cost of the housing option which was selected as optimal. Notice that when the increase in allowance is below approximately 3.6%, the option identified as least expensive is "House Off-Base." The cost associated with that least expensive option varies as the annual increase in VHA & BAQ changes. At an annual increase of approximately 3.6%, the least expensive housing option changes to "Maintain Housing." The cost of Housing Off-Base has increased above the cost of maintaining the housing, and therefore the decision changes. At this point, the costs stay constant because the annual increase in VHA & BAQ does not effect the cost of Maintaining the Housing. The result is that the cost of the least expensive option can be graphed and points at which a decision change occurs can be identified using this sensitivity analysis.

If the actual point of the value used is close to the decision change point, then a slight change in the variable may cause the housing decision to change. This proximity of the actual value to the decision change point will show the user the level of uncertainty in the variable that could cause a decision change

3.5 Model Assumptions

This model makes certain assumptions in its decision making process as follows:

1) The Lifetime of a House is 65 years with 2 Revitalizations.
2) The Housing retired at 65 years of age will be replaced with New Housing
3) Costs associated to all Air Force Housing will be similar to the costs associated to housing in AFMC.

4) The average annual maintenance cost calculated for AFMC housing applies to an average aged house.

The first assumption is taken from the standard Air Force Policy that schedules a house to be Revitalized at the 25^{th} and 45^{th} year of it's life to extend the total life of the house to 65 years. The computer model adjusts the housing in question when it is not possible to meet the Revitalization dates. But the model still operates under the assumption of a 65 year lifespan of a house [Jameson; 1997].

The second assumption of replacing a retired house On-Base with a new house On-Base is used to provide a consistent time period for comparison. After the standard Air Force policy of 2 revitalizations, new housing is the best way to ensure that the On-Base housing has efficient systems and safe structural characteristics.

The third assumption is related to the source of housing information used to build this model. Working with the Housing Programmers at AFMC provided access to all of the information related to the bases under their command. Considering the extensive range of housing under this command, an accurate assumption of consistency across the Air Force was assumed because AFMC has bases in many parts of the United States. The area cost factor is used to adjust the averages depending on the location of the base.

The assumption that AFMC housing is of an average age is made in order to build the maintenance cost curve. According to the AFMC Housing Programmers, the randomness of revitalizations on AFMC On-Base housing (which bring the cost of maintenance on an existing house back to the same cost of maintenance on a new house) allows for this to be a safe assumption.

3.6 Summary

The methodology involved in determining the least cost combination of housing is the application of accepted economic equations under a specific set of circumstances. By combining the optimal decision for each of the six rank categories, the overall decision model will inform the user of what the least cost combination of housing will be for any Air Force Installation. Using this model, the cost of that combination of housing can be compared to the cost of the current Air Force Strategy. The difference in the costs is the potential savings of the installation if the recommended combination of housing is used. Performing a sensitivity analysis on the variables involved in the decision allows the user to see how sensitive each variable is to change.

The development of the overall decision model in this thesis gives the user the results of this economic analysis in a convenient fashion. The Excel spreadsheet provided will allow any installation to be studied by simply changing the input variables. The next step is to collect actual data for an installation and analyze the results of the model. Chapter four determines the optimal combination of housing from the data available on Edwards Air Force Base.

IV. Results and Analysis

4.1 Introduction

Once all of the data has been gathered for a particular installation, the least cost combination of On and Off-Base housing over the next 65 years can be calculated. The overall model will present the user with the annualized cost for the installation, as well as the cost for housing each of the six categories of personnel. Along with the costs, a summary of how many families to house On-Base, Off-Base, and the number of houses to build is also given. All of this information is presented to the user on a convenient spreadsheet. With this information, the user will be informed of the most economically efficient housing combination for the local area of the installation.

In order for the user to determine the sensitivity of the variables input into the model, a sensitivity analysis can be performed. Analyzing the variables in the model will allow the user to identify the variables that have most influence on which housing option to use. It will also allow the user to determine when a change in these variables would cause a decision in the use of a housing option. In order to present the results of the model, data for Edwards Air Force Base was gathered. The data for Edwards AFB was used because it was readily available from the housing programmers at AFMC. The results and analysis of this data are presented in this chapter.

4.2 Results

The user input for Edwards Air Force Base is summarized below:

- Amount of VHA & BAQ

E1-E3 - $460
E4-E6 - $611
E7-E9 - $812
O1-O3 - $775
O4-O5 - $1009
O6-UP - $1049

- Age of the Existing Housing (Several Groups of housing in some Categories)

E1-E3 -

Group	1	2	3	4	5	6	7	8
Age (yrs)	53	39	47	45	49	32	3	2

E4-E6 -

Group	1	2	3	4	5	6	7	8
Age (yrs)	53	39	47	45	49	32	3	2

E7-E9 -

Group	1	2	3	4	5	6	7	8
Age (yrs)	45	39	39	-	-	-	-	-

O1-O3 -

Group	1	2	3	4
Age (yrs)	41	38	-	-

O4-O5 -

Group	1	2	3	4
Age (yrs)	38	-	-	-

O6-UP -

Group	1	2	3	4
Age (yrs)	38	-	-	-

- Time since last Revitalization

E1-E3 -

Group	1	2	3	4	5	6	7	8
Years	10	39	15	28	12	32	3	2

E4-E6 -

Group	1	2	3	4	5	6	7	8
Years	10	39	15	28	12	32	3	2

E7-E9 -

Group	1	2	3	4	5	6	7	8
Years	28	39	31	-	-	-	-	-

O1-O3 -

Group	1	2	3	4
Years	14	38	-	-

O4-O5 -

Group	1	2	3	4
Years	38	-	-	-

O6-UP -

Group	1	2	3	4
Years	38	-	-	-

- Amount of Existing On-Base Houses

E1-E3 -

Group	1	2	3	4	5	6	7	8
Amount	1	19	55	41	10	0	0	0

E4-E6 -

Group	1	2	3	4	5	6	7	8
Amount	9	174	494	369	90	2	20	14

E7-E9 -

Group	1	2	3	4	5	6	7	8
Amount	40	250	25	-	-	-	-	-

O1-O3 -

Group	1	2	3	4
Amount	100	179	-	-

O4-O5 -

Group	1	2	3	4
Amount	109	-	-	-

O6-UP -

Group	1	2	3	4
Amount	22	-	-	-

- Number Military Families at the Base

  E1-E3 - 167
  E4-E6 - 1433
  E7-E9 - 333
  O1-O3 - 279
  O4-O5 - 93
  O6-UP - 22

- Available Off-Base Housing

  E1-E3 - 332
  E4-E6 - 475
  E7-E9 - 75
  O1-O3 - 163
  O4-O5 - 14
  O6-UP - 2

- Number of Mission Essential Military Families who must live On-Base

  E1-E3 - 0
  E4-E6 - 0
  E7-E9 - 11
  O1-O3 - 59
  O4-O5 - 4
  O6-UP - 13

- Demolition Cost of an Existing House - $8,000
- Construction Cost of a new House - $139,000
- Revitalization Cost of a House - $102,000
- Average Annual Maintenance Cost - $3,096
- Time until next Revitalization - AF Policy used
- Housing Factor

  E1-E3 - 0.88
  E4-E6 - 0.88
  E7-E9 - 0.93
  O1-O3 - 0.93
  O4-O5 - 1.04
  O6-UP - 1.33

- Area Cost Factor - 1.21
- Interest Rate - 0.063
- Inflation Rate - 0.025
- Yearly Increase in VHA & BAQ - 0.03

The results of the model using the data for Edwards Air Force Base show that Housing military families Off-Base is the least expensive option in most cases. In many of the rank categories, there is not enough housing available Off-Base to account for all of the military families. In these cases, the existing housing is used because it is less expensive to maintain than to build new housing. The option of building new housing is never recommended for Edwards Air Force Base. A complete listing of the results for each category is shown below. All costs are annualized costs for the next 65 years.

Results for Edwards AFB:

Cost of Optimal Comb. = $38,681,074.77
Current Strategy Cost = $41,079,305.01

E1-E3 -

Group	1	2	3	4	5	6	7	8
Action	Do not use	Do not use	Do not use	Do not use	Do not use	Do not use	Do not use	Do not use

Off-Base & Demolition Cost of Unused Housing =	$1,739,515.76	Housed Off-Base =	167
On-Base Cost =	$0.00	Housed On-Base =	0
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For E1-E3 =	$1,739,515.76		167

The results for the first category, E1-E3, show that there are eight different groups of housing On-Base which can be used for this category. However, all of the housing groups should not be used because it would be less expensive to house the personnel in this category Off-Base than to maintain those groups of housing or to build new housing. The total annualized cost to house this group of personnel is $1,739,515.76. The least cost combination of housing this category's 167 families is to house all Off-Base, and to demolish the existing housing. The

demolition cost of the 126 houses in this rank category has been added to the cost of housing the military families Off-Base above.

E4-E6 -

Group	1	2	3	4	5	6	7	8
Action	Constrained Use	Constrained Use	Constrained Use	Constrained Use	Do not use	Do not use	Maintain	Maintain

Off-Base & Demolition Cost of Unused Housing =	$6,409,004.44	Housed Off-Base =	475
On-Base Cost =	$16,903,776.83	Housed On-Base =	958
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For E4-E6 =	$23,312,781.26		1433

The results for the E4-E6 category show that there is some constrained use of the existing housing in groups 1-4. The reason for this constrained use is that once all of the available housing Off-Base is occupied, the remaining families are placed in the existing housing because it is less expensive to use than to build new housing. Housing Groups 7 & 8 are maintained because maintaining those two groups is the least expensive option. The housing units in groups 5 & 6, as well as the housing in the constrained groups that were not used, are to be demolished. The total annualized cost for the E4-E6 category is $23,312,780. The results for all other categories are shown below.

E7-E9 -

Group	1	2	3	4	5	6	7	8
Action	Constrained Use	Constrained Use	Do not use	-	-	-	-	-

Off-Base & Demolition Cost of Unused Housing =	$1,352,365.15	Housed Off-Base =	75
On-Base Cost =	$4,963,724.25	Housed On-Base =	258
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For E7-E9 =	$6,316,089.40		333

O1-O3 -

Group	1	2	3	4
Action	Maintain	Constrained Use	-	-

Off-Base & Demolition Cost of Unused Housing =	$2,833,037.78	Housed Off-Base =	163
On-Base Cost =	$1,984,849.37	Housed On-Base =	116
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For O1-O3 =	$4,817,887.15		279

O4-O5 -

Group	1	2	3	4
Action	Maintain	-	-	-

Off-Base & Demolition Cost of Unused Housing =	$9,944.91	Housed Off-Base =	0
On-Base Cost =	$1,937,514.60	Housed On-Base =	93
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For O4-O5 =	$1,947,459.52		93

O6-UP -

Group	1	2	3	4
Action	Constrained Use	-	-	-

Off-Base & Demolition Cost of Unused Housing =	$46,611.46	Housed Off-Base =	2
On-Base Cost =	$500,730.21	Housed On-Base =	20
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For O6-UP =	$547,341.68		22

The results above show that the least cost combination of housing for Edwards AFB will cost $38,681,074.77 per year, annualized over the next 65 years. This cost can be compared to the calculated cost of the current Air Force Strategy, which is to maintain the existing housing and house all additional families Off-Base. The cost of the current AF Strategy is $41,079,305.01 per year, annualized over the next 65 years. The difference results in an annualized savings of $2,398,230.24. The following graph shows the savings of each rank category:

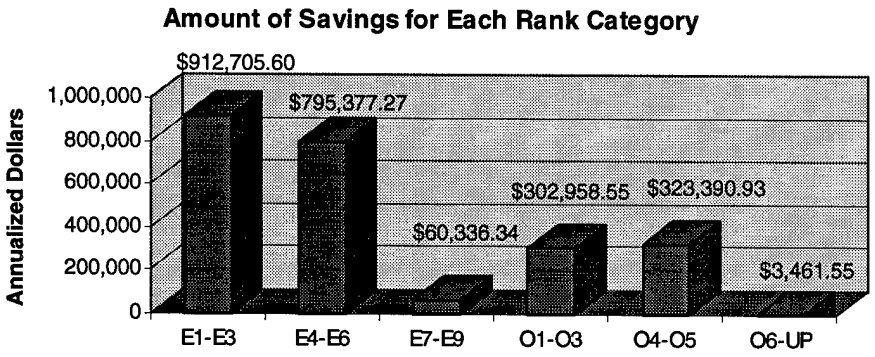

Figure 4.1 Savings for each Rank Category using the Optimal Combination

The graph in Figure 4.1 shows that there are possible savings in all six of the rank categories. The opportunity to save the most money occurs in the E1-E3 rank category at $912,700, with the E4-E6 category just below at $795,300. It is also evident from this graph that the potential to save money in housing the enlisted military families is almost twice that of the military officer's families. The reason for this opportunity is partly due to the fact that there are more enlisted than officer families at the base.

Breaking the savings down per military family in each respective category results in a different observation.

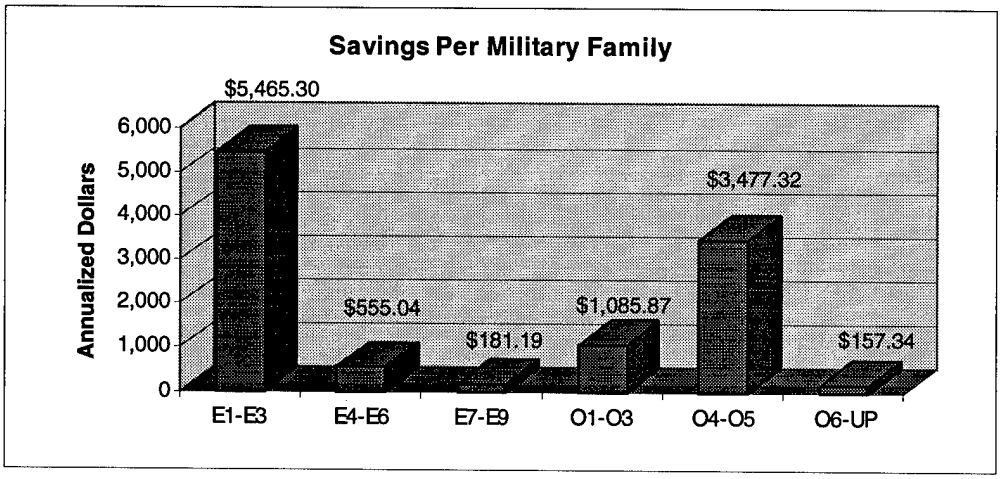

Figure 4.2 Savings Per Military Family using the Optimal Combination

It is clear that the E1-E3 rank category has the highest potential savings per family, but the O4-O5 category is not far behind. Although the O4-O5 and O1-O3 rank categories have the second and third highest savings per military family, the greatest opportunity to save is with the enlisted ranks. This information instructs the user to concentrate their efforts on the enlisted families first. Once those families have been housed according to the recommended combination, the focus can be shifted to the officer military families in order to take advantage of the entire potential savings.

The results of the model for Edwards AFB show that the current AF Strategy does not result in the least cost combination of housing for the installation. The base could have an annualized savings of over 2.3 million dollars by housing their personnel in a more economically efficient manner. Once the results have been presented, the user can now move into the analysis of the variables input into the model.

4.3 Analysis of the Variables

In order to determine the sensitivity of the variables, an analysis can be run on each variable to determine when a decision change might occur. Graphing a particular group of housing's cost over the range of the changing variable will show the user where a decision change would occur. Ranging the variables from 50% to 150% of their original value gives realistic boundaries to this analysis.

The analysis will be started by using the single group of housing for the O6-UP category. The results above show that this housing group should not be maintained because it is less expensive to house military families in this category Off-Base. The decision not to use this housing may have been different if the variables input into the model had been slightly different.

For example, if a 6% interest rate was used instead of a 6.3% interest rate, maintaining this housing group may have been the least expensive option. To determine if a decision change would occur, the variables input into the model are evaluated.

The first variable evaluated is the interest rate. Ranging this from 50% of its original value (3.15%) to 150% of its original value (9.45%) results in the following graph, with the cost of the least cost housing option on the Y-axis. To produce the graphs below, the variable in question is changed while all other variables remain constant.

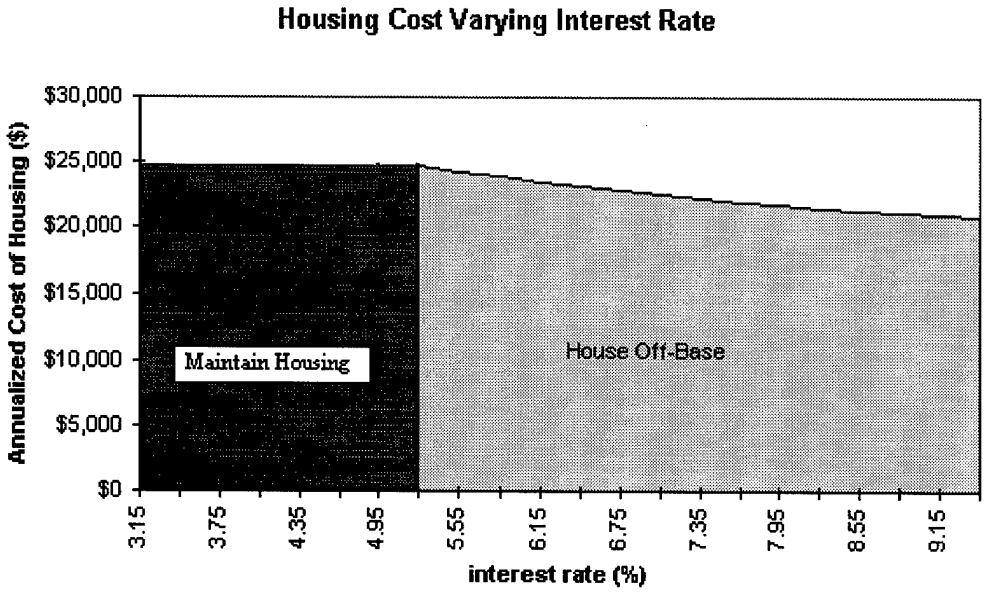

Figure 4.3 Housing Cost Varying Interest Rate (O6-UP, housing group #1)

Figure 4.3 shows that the interest rate used, 6.3%, is on the right side of the vertical line running through the curve. This vertical line indicates the point at which a decision change occurs. Having the actual interest rate fairly close to the point at which a decision change would occur shows that this is a sensitive variable in the calculation. Had the interest rate been estimated below 5.25%, the decision to use this housing would have been different. A similar graph can be produced using the inflation rate.

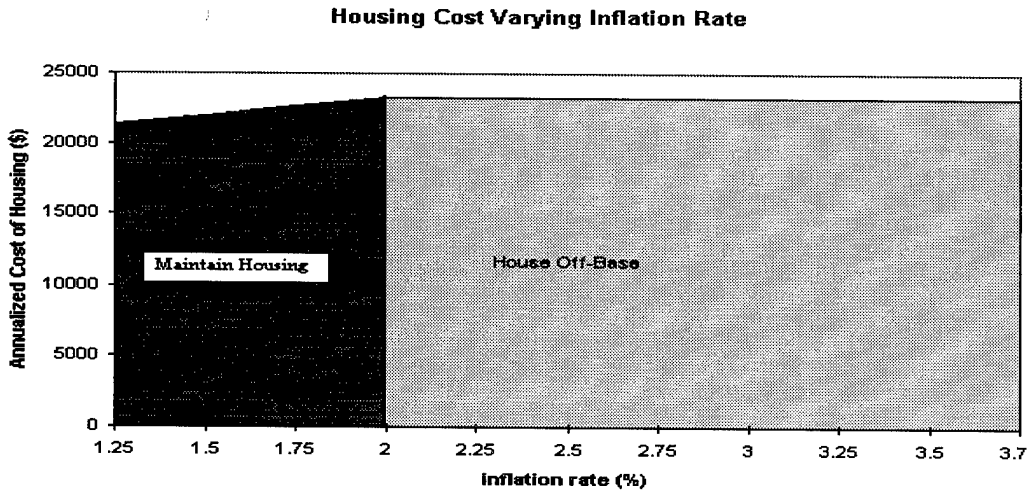

Figure 4.4 Housing Cost Varying Inflation Rate (O6-UP, housing group #1)

The inflation rate used in this analysis is fairly close to the point of the decision change. Therefore, like the interest rate, the inflation rate is a sensitive variable in this calculation. If the inflation rate was estimated below 2.0%, there would be a decision change. The next variable to be considered is the annual increase in BAQ & VHA. Varying the 3% increase from 1.5% to 4.5% results in the following graph:

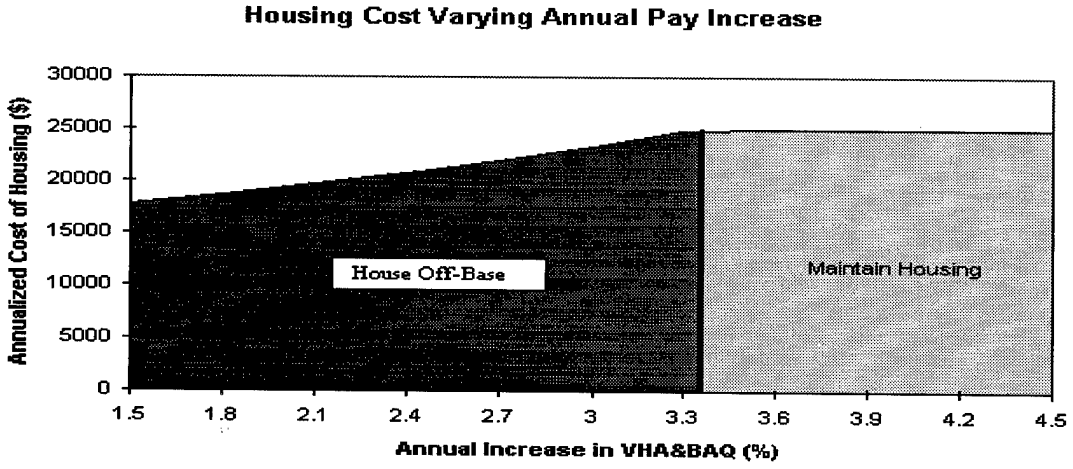

Figure 4.5 Housing Cost Varying Annual Increase in VHA&BAQ (O6-UP, group #1)

Again the value used of 3.0% is close to the decision change point which makes this a sensitive variable. This same process can be used to determine how a change in any of the input

variables would change the decision for a particular group of housing. The group of housing that has been concentrated on above is the only housing group for the O6-UP category. The reason that a slight change in the variables could cause a decision change is because there is not much difference in the cost of maintaining this particular group of housing and the cost of housing a family in this category Off-Base. The annualized cost of maintaining a house in group #1 for O6-UP is $25,000 for the next 65 years, while the annualized cost of housing a family in the O6-UP category Off-Base is $23,300 for the next 65 years. The closeness of these costs cause a slight change in some variables to change the decision.

A second group of housing that can be considered is housing group #3 for the E1-E3 category. When the same type of analysis of variables is performed on this group of housing that was performed on the group above, the results are much different. When the interest rate is varied from 3.15% to 9.45% the following graph is produced:

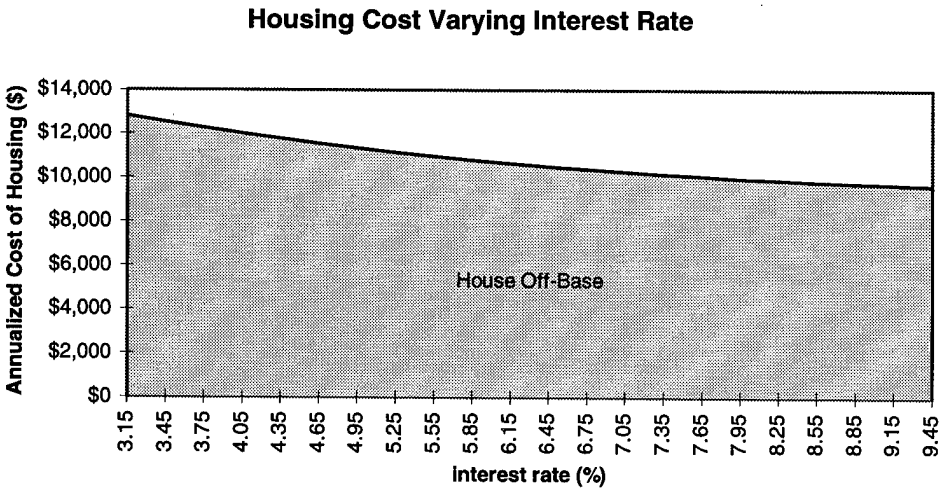

Figure 4.6 Housing Cost Varying Interest Rate (E1-E3, housing group #3)

The decision to house Off-Base is never changed by varying the interest rate from 50% to 150% of its original value. In this case, the interest rate used in the decision to house Off-Base is

not a sensitive variable to the calculation. The same type of graph can be constructed for the inflation rate.

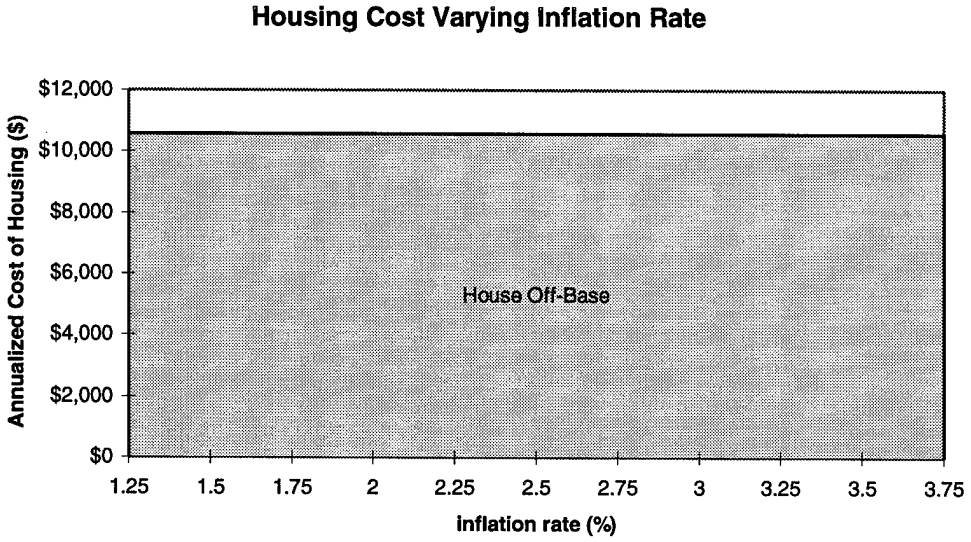

Figure 4.7 Housing Cost Varying Inflation Rate (E1-E3, housing group #3)

Like varying the interest rate, varying the inflation rate from 50% to 150% of its original value does not have an effect on the decision to house these families Off-Base. In fact, the graph shows that the cost of this option never changes as the inflation rate is varied. This is because the inflation rate is not used in the calculation of the cost of housing military families Off-Base, the annual increase in VHA & BAQ is used to make up for inflation. Therefore, the inflation rate used in the decision to house these families Off-Base is not a sensitive variable. The next variable to be examined is the annual increase in VHA & BAQ. The graph produced when varying this variable from 1.5% to 4.5% is:

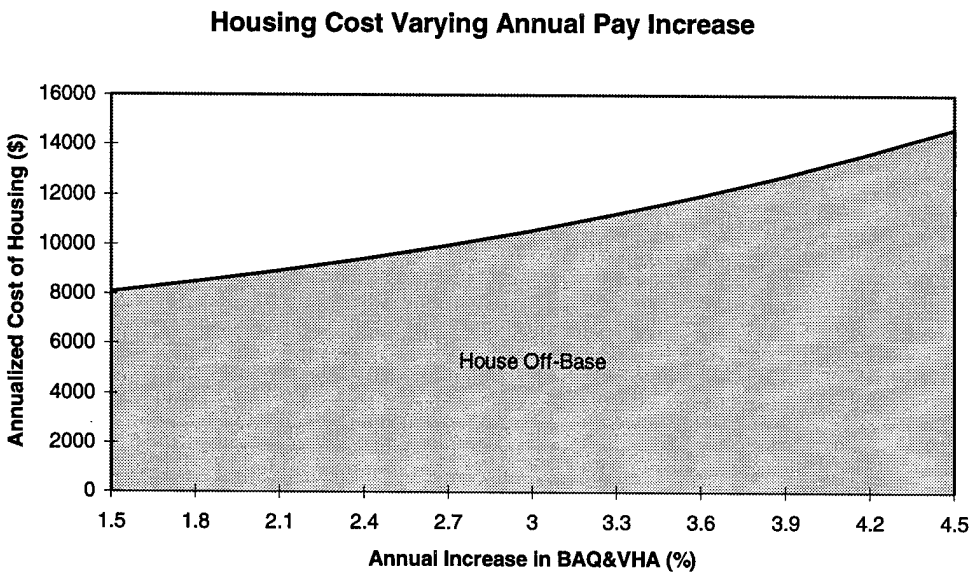

Figure 4.8 Housing Cost Varying Annual Increase in VHA & BAQ (E1-E3, group #3)

Figure 4.8 shows that the cost of housing a military family Off-Base rises as the annual increase in VHA & BAQ rises. However, a decision change is never reached within the 50% to 150% range that is used to create the graph above. The increase in VHA & BAQ is not a sensitive variable in the decision not to use this group of housing. This analysis could be continued through all of the input variables to determine if there is a sensitive variable in this decision.

Unlike the single housing group for the O6-UP category, this group of housing does not have many, if any, sensitive variables. The reason is that the cost of maintaining a house in this group of housing is much more expensive than the cost of housing a family in this category Off-Base. The annualized cost of maintaining a house in this group is $15,500 for the next 65 years, while the annualized cost of housing one of the families in this category Off-Base is $10,550 for the next 65 years. This large difference in cost allows a lot of flexibility in the variables without changing the decision to house these families Off-Base. Using the approach above, all of the

housing groups for each category can be analyzed to determine which variables have the most influence on the decision of which housing option is least expensive.

Another type of analysis that can be performed on the variables is called two-way sensitivity analysis. As the name implies, it allows two variables to be examined at one time rather than just one variable as in the previous analysis. Graphing the least cost option of housing with one variable on the x-axis and another variable on the y-axis allows the user to determine what the least cost option of housing is for any combination of the two variables. While any combination of two variables can be examined, it is important to remember that all other variables are held constant. Once all of the variables had been determined for Edwards Air Force Base, the Housing Programmers at AFMC were asked to identify the variables in which they had the least amount of confidence [Jameson, 1997]. The response from the programmers was that there were only two variables which they thought may be slightly off. The two variables that they identified were the Construction Cost of a new home ($139,000) and the Revitalization Costs ($102,000). Although they agreed that the values used for these two variables were the best approximations, they still felt that these were the two variables in which they had the least amount of confidence.

To further evaluate the Construction Cost and Revitalization Cost, a two-way sensitivity analysis was performed. It is important to remember that all variables are held constant except the two that are analyzed in the two-way sensitivity analysis. The following graph is the result based on housing group #3 for the E1-E3 rank category :

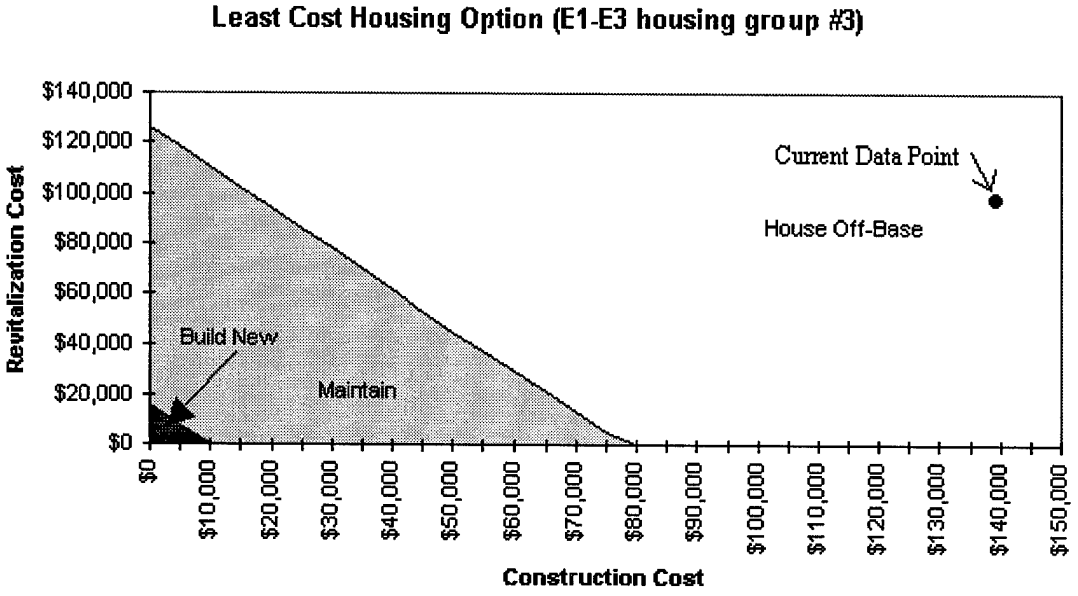

Figure 4.9 Two-way Sensitivity Analysis on Const. and Rev. Cost (E1-E3 housing group #3)

The graph above shows that the least cost housing option for this housing group is "House Off-Base" when the construction Cost is $139,000 and the Revitalization Cost is $102,000. This agrees with the recommendation of the model. The graph above also shows the user the least cost housing option for any combination of the two variables. For example, if the Construction Cost was $50,000 and the Revitalization Cost was $20,000, the least cost housing option is to "Maintain" this housing group. Using this graph, the decision makers immediately know the least cost housing option for this particular housing group given any combination of the two variables. In this particular case, it is obvious that the result is almost always to house Off-Base, showing that these variables are not very sensitive.

A similar graph can be produced for any of the other housing groups. Using the housing group for the O6-UP rank category shows that these variables are sensitive to which housing

option is used in this case. A slight change in either of these costs would cause the decision of housing these families Off-Base to change.

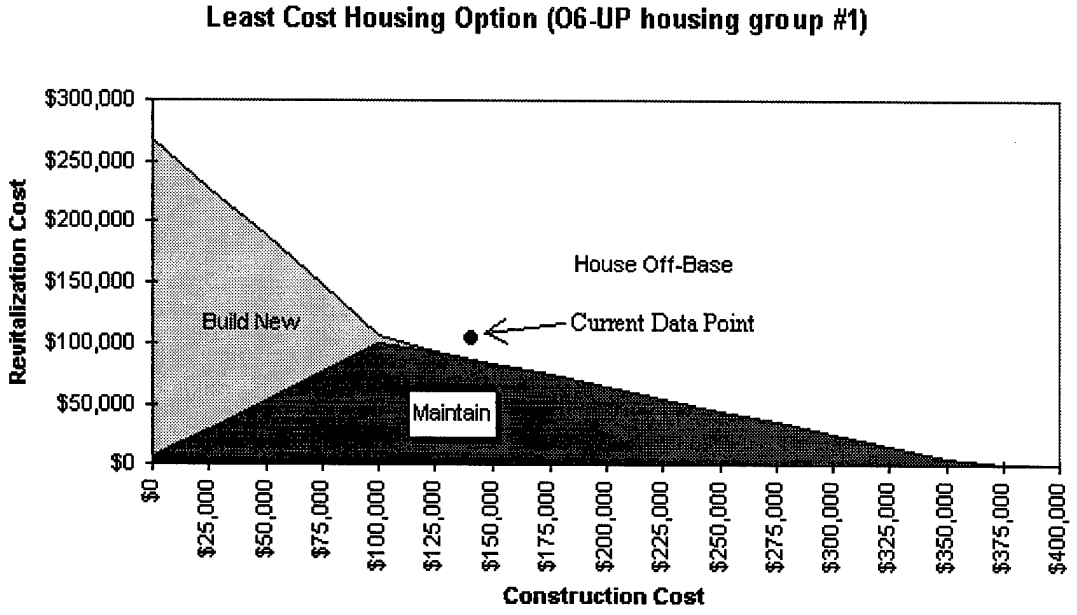

Figure 4.10 Two-way Sensitivity Analysis on Const. and Rev. Cost (O6-UP housing group #1)

The graph above coincides with the recommendation of the model that this housing group should not be maintained and these families should be housed Off-Base. The Construction and Revitalization Costs could be analyzed in this manner for any of the housing groups.

The difference in the housing groups for any particular rank category are distinguished by two variables, the Age of the Housing and the Years Since the Last Revitalization. Performing a two-way sensitivity analysis on these variables allow the user to look up the least cost housing option for any of the housing groups in a particular rank category. Producing this graph for the O6-UP rank category results in the following figure.

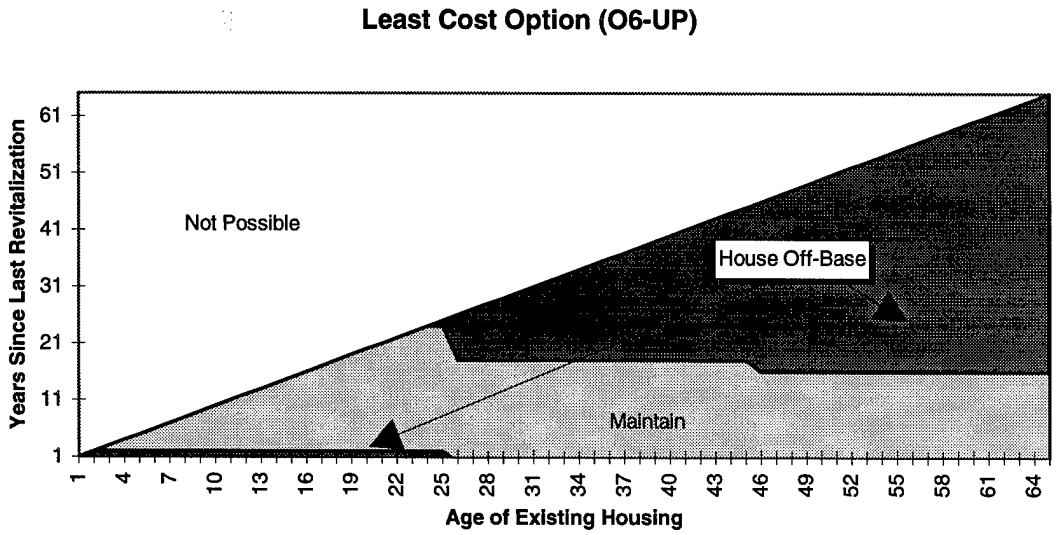

Figure 4.11 Two-way Analysis on Age of Existing and Years since Last Revit.

(O6-UP Rank Category)

Notice that half of the graph above is a region that is "Not Possible." This is an impossible region because the Years Since Last Revitalization can never be greater than the Age of the Housing. The remaining half of the graph results in the least cost option of housing as either "House Off-Base" or "Maintain." The Maintain region tells the user to utilize any housing group that falls in that region. The "House Off-Base" region informs the user that any housing group that falls in that region is more expensive to maintain than the option of housing Off-Base. The recommendation is not to use a housing group that falls in the "House Off-Base" region.

The smaller region of the two "House Off-Base" regions reinforces the fact that it is less expensive to house a family Off-Base than to build new housing. Notice that this small region only occurs in year 1 of the variable "Years since the last Revitalization." This first year reflects the building of a new house, and maintaining a house that is starting in the year of construction is

the same as building a new house. The model shows that housing families Off-Base is less expensive than building new, so the small "House Off-Base" region of the graph is produced.

The housing option of Building New is never shown on this graph because it is less expensive to house a military family in this category Off-Base than to Build New. The costs of Building New and Housing Off-Base are not effected by these two variables, so only the lowest cost option of these two will be shown on this graph.

Producing this same graph for all of the rank categories reveal that most of the graphs are similar. However, the E1-E3 category shows that On-Base housing should never be maintained for these military families because it is always less expensive to house them Off-Base. Figure 4.11 illustrates this category's two-way sensitivity analysis graph for the Age of the Existing Housing and the Years Since the Last Revitalization.

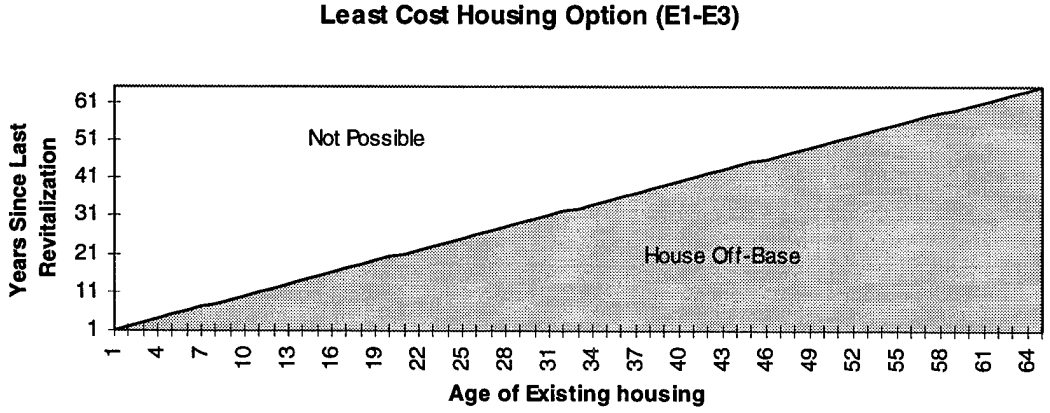

Figure 4.12 Two-way Analysis on Age of Existing and Years since Last Revit. (E1-E3 Rank Category)

Each individual graph for the six rank categories can be found in Appendix C. These graphs provide a tool for Edwards Air Force base to quickly reference what should be done with any existing housing group.

Most of the variables in this model are uncontrollable. In the previous analysis, variables such as the interest rate, construction cost of a new home, and the age of existing housing are examined, but are beyond the control of the decision makers. The resulting graphs show where decision changes will occur if these variables change; however, decision makers can not change these variables. Therefore, it may be useful to perform a two-way sensitivity analysis once a controllable variable has been changed. The Annual Increase in BAQ & VHA is a controllable variable and is changed from 3.0% to 5.5% for the next two-way sensitivity analysis. The same two-way analysis discussed above was performed on the Age of the Existing Housing and the Years Since Last Revitalization with the Annual Increase in VHA & BAQ at this higher rate. The graphs produced are significantly different than the graphs produced at the Annual Increase of 3.0%. This 2.5% addition to the estimated increase causes the option of housing Off-Base to disappear from all rank categories except E1-E3; however, the decision is not to always maintain the existing housing. The graph produced for the E1-E3 category is shown in Figure 4.13 below.

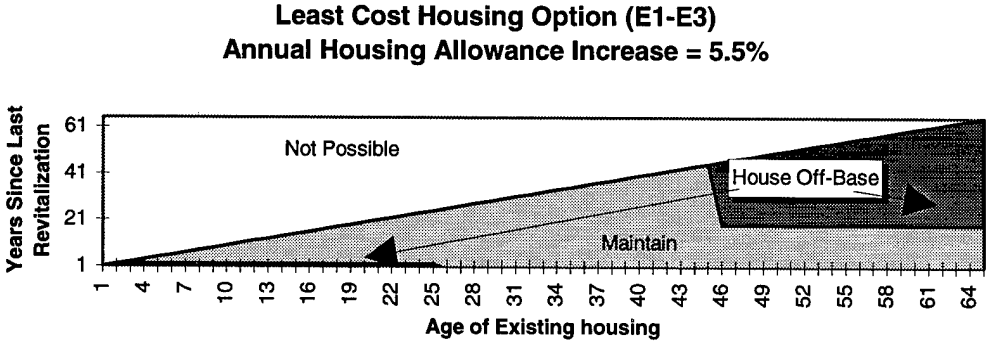

Figure 4.13 Two-way Analysis on Age of Existing and Years since Last Revit. When Annual Housing Allowance Increase is 5.5% (E1-E3 Rank Category)

This graph shows that by increasing the Annual Increase in Housing Allowance, the installation should utilize much more of the existing housing On-Base. The region that recommends the user to house families Off-Base is when the existing housing is over 45 years old and has not been revitalized in over 18 years. Producing this graph for each of the other 5 rank categories results in the exact same graph for each. This graph is shown in Figure 4.14 below.

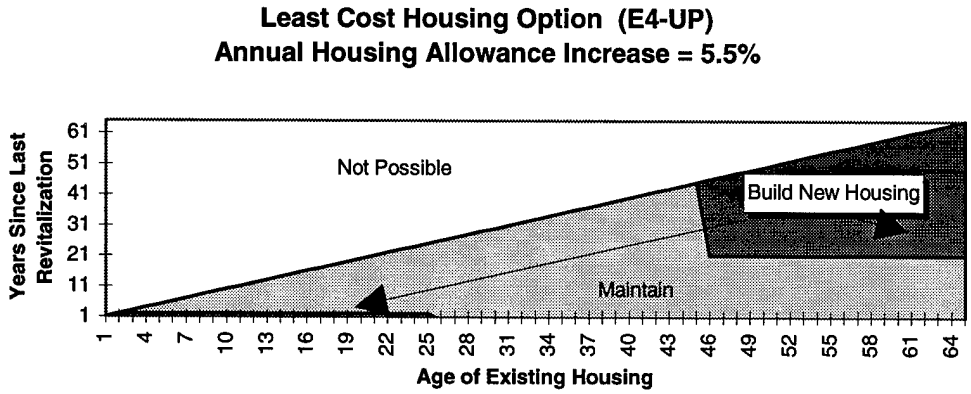

Figure 4.14 Two-way Analysis on Age of Existing and Years since Last Revit. When Annual Housing Allowance Increase is 5.5% (E4-UP Rank Categories)

Figure 4.14 shows that when the Annual Increase in VHA & BAQ is 5.5%, these families should never be housed Off-Base. The existing hosing should be maintained unless it is over 45 years old and has not been revitalized in over 20 years. The conclusion drawn from this additional analysis is that a greater increase in the compensation given to military families living Off-Base will change the economically optimal combination. The result of this change is to utilize most of the existing On-Base housing rather than to house as many families Off-Base. By altering a controllable variable, the results reflect that more personnel should be housed On-Base when the compensation to live Off-Base increases.

4.4 Summary

Overall, this model provides the user with the economically optimal combination of housing for an Air Force Installation. The total cost of this combination is presented and compared to the total cost of the current Air Force Strategy. The difference in those two costs is the savings to the installation, if the choice is made to use the least cost combination. Once the least cost combination of housing has been identified, an analysis of the variables can be performed. Concentrating on a specific group of housing allows the user to test the sensitivity of the variables to that specific group. The two-way sensitivity analysis allows the least cost option of housing to be found for any combination of two variables. Using sensitivity analysis, any of the variables can be examined to identify decision changes.

The results of the model also give the user the individual cost of housing for each separate category, as well as the number of families to be housed in existing On-Base housing, New On-Base housing, and Off-Base housing. Using the results of this model will allow the user to be completely informed when making a decision on how to house the military families at an Air Force Installation.

V. Findings and Conclusions

5.1 Findings

The goal of this analysis was to develop a method of determining the economically optimal combination of On and Off-Base housing for an Air Force Installation. The least cost combination of housing was defined as the combination of housing that resulted in the lowest annualized cost. Annualized cost was used instead of Net Present Value to show the user an approximation of the yearly cost of the housing. This least cost combination can be used as part of the decision process in determining which bases should receive funding for new construction. The least cost method of housing military families is always a combination of the following three options:

1) **Building New On-Base Housing** - If all of the existing On-Base housing is occupied, new housing may be built.
2) **Maintaining Existing On-Base Housing** - A military family may be housed in an existing house On-Base.
3) **Housing Military Families Off-Base** - It is also possible to pay a military member a housing allowance and have the military family find a source of housing Off-Base.

Using a combined economic and decision analysis approach to this problem, a decision tool was built that identifies the least cost combination of the options above. The model built takes the economic conditions of the surrounding area into consideration and determines the optimal solution for any Air Force Installation. The ability to adapt to any installation is an

integral feature of the model allowing variations to be used in the civilian arena as well as the military. The following assumptions were made in the development of the model:

1) The Lifetime of a House is 65 years with 2 Revitalizations.
2) The Housing retired at 65 years of age will be replaced with New Housing
3) Costs associated with all Air Force Housing will be similar to the costs associated with housing in AFMC.
4) The average annual maintenance cost calculated for AFMC housing applies to an average aged house.

The research objective was to determine the economically optimal combination of housing for an Air Force Installation considering the economic conditions of the existing area. This objective was accomplished in the development of the model. The user will not only be informed of the least cost combination of housing and its cost, but also with the cost of housing using current Air Force strategy. The comparison of those two costs will show the potential savings of the installation when using the least cost combination.

The results of the model for Edwards Air Force Base show that the data is readily available for any installation, and that the economically optimal combination may not be achieved by the current Air Force Strategy. These results show that there is a potential annualized savings of over $2.3 million over the next 65 years. Edwards Air Force Base is one of the larger bases in AFMC; however, the potential to save money will be present at any Air Force Installation. Using the model developed in this thesis would ensure that every installation is pursuing the economically optimal combination of housing.

The results also show that the economically optimal combination of housing involves housing most military families Off-Base. In addition, the most money is saved by concentrating on housing the enlisted military families Off-Base. The reason for housing lower ranking military members Off-Base is that they do not require as much compensation as the higher ranking members. The difference in compensation paid to officers and enlisted members to live Off-Base is greater than the difference in costs associated to the housing requirements for the two groups On-Base; therefore, making it less expensive to house those lower ranking members Off-Base.

Housing the lower ranking military members On-Base has always been considered part of the duty of the military in taking care of it's troops. Although it is not economically optimal to house these members On-Base, it can be accepted as a political decision to provide a higher quality of life to those military families. This observation supports the idea of privatization. Privatization would help reduce expenses by exchanging the VHA and BAQ payments for military families in return for maintaining the housing for those families. Guaranteeing the civilian company 100% occupancy gives them business while taking the burden of On-Base housing away from the installation.

Although this model has concentrated on single Military Family Housing, it could just as easily be used for Multi-Family dwellings. First, the costs associated to a duplex or apartment building could be divided by the number of families to live in that dwelling. Once the input variables were adjusted, the least cost combination could be found. Another possibility for the use of this model is on dormitories. Using the cost associated to each occupant of the dormitory, a determination can be made of who should be housed in the dormitory, who should be housed Off-Base, or when it is less expensive to build new dormitories. The ability of this model to adapt to any situation with a change of the input variables allows for a wide range of use.

Knowing the cost of housing for each rank category allows the user to concentrate on the areas of Base Housing that need the most attention. The user will know which rank categories need housing and can validate that need by showing the potential savings to the installation when using the economically optimal option. Having proof in the form of economic savings will allow a Base to build a housing strategy and defend it when challenged.

5.2 Recommendations for Future Research

Throughout the development of the model and the analysis of the data, opportunities for future research were identified. Some of these ideas, along with a brief description are listed below:

5.2.1 Incorporation of Qualitative Factors. The model could be adapted to account for qualitative factors such as personal preferences or individual needs. Using these qualitative factors, the best combination of housing could be determined that would be optimal taking the qualitative factors into consideration. The decision makers would then have to decide if it was more important to satisfy the desires of the military personnel or operate with the economically optimal combination of housing.

5.2.2 Adaptation of the Model to be Used by Corporations. It would be very easy to adapt this model to be used by civilian corporations. Any corporation that owns apartment buildings or houses could use the model to determine if the buildings should be renovated or new ones should be built. Schools could use this model to determine whether or not to use older housing or dormitories for the students. Changing the lifetime assumption of 65 years is possible by changing the equations used in the calculations.

5.2.3 Using the Model for Other Branches of the Military. Another possibility would be to adapt this model to be used by other branches of the military. The requirement to house military families is shared throughout all branches of the Armed Forces, and this model could aid any of them in deciding how to house their military members.

5.2.4 Incorporation of Uncertainty. The use of uncertainty and the determination of the probability of the variables is another way to make this model more accurate. The use of uncertainty would produce a range of values that would encompass the variable. From this range of values the probability of a decision change could be calculated by the user.

5.3 Summary

The decision of how much On-Base Military Family Housing to provide involves the commitment of millions of dollars. Current policy requires that this decision be made without the information of what combination would be the least expensive. The current Air Force strategy is to use all existing On-Base housing, and then to look to the local community to house the additional military families. Only when the local community can not house the additional families will they consider constructing new housing. This current strategy does not account for the fact that in some cases maintaining existing On-Base housing is not the least cost option. There are cases when it is less expensive to build new housing or to pay a military family to live Off-Base.

The model developed in this thesis determines the least cost combination of housing and identifies this combination to the user. Even if this least cost combination is not used, the decision makers can use this information to be better informed and make better decisions.

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Appendix A: Area Cost Factors (as of 28 MAY 1997)

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
ALABAMA		0.83
	MOBILE	0.82
	MONTGOMERY	0.84
	ANNISTON ARMY DEPOT	0.81
	FORT MCCLELLAN	0.82
	FORT RUCKER	0.80
	MAXWELL AIR FORCE BASE	0.84
	MOBILE AREA	0.82
	REDSTONE ARSENAL	0.85
ALASKA		1.59
	ANCHORAGE	1.50
	FAIRBANKS	1.68
	ADAK NAVAL STATION	2.40
	EIELSON AIR FORCE BASE	1.73
	ELMENDORF AIR FORCE BASE	1.55
	FORT GREELY	1.87
	FORT RICHARDSON	1.50
	FORT WAINWRIGHT	1.73
	SHEMYA AIR FORCE BASE	2.46
	CLEAR AIR FORCE BASE	1.86
ARIZONA		0.95
	FLAGSTAFF	0.97
	TUSCON	0.93
	DAVIS MONTHAN AIR FORCE BASE	0.93
	FORT HUACHUCA	0.97
	LUKE AIR FORCE BASE	0.96
	NAVAJO ARMY DEPOT	0.95
	YUMA MCAS	1.05
	YUMA PROVING GROUND	1.05
ARKANSAS		0.83
	FORT SMITH	0.82
	PINE BLUFF	0.84
	FORT CHAFFEE	0.81
	LITTLE ROCK AIR FORCE BASE	0.80
	PINE BLUFF ARSENAL	0.84

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
CALIFORNIA		1.17
	SAN DIEGO	1.15
	SAN FRANCISCO	1.18
	BEALE AIR FORCE BASE	1.23
	CAMP PENDLETON MARINE CORPS	1.14
	CENTERVILLE BEACH	1.11
	CHINA LAKE NAVAL WEAPONS CENTER	1.29
	EDWARDS AIR FORCE BASE	1.21
	EL CENTRO NAVAL AIR FIELD	1.20
	EL TORO	1.11
	FORT HUNTER LIGGETT	1.28
	FORT IRWIN	1.23
	FORT ORD	1.13
	LOS ANGELES AREA	1.11
	MARCH AIR FORCE BASE	1.14
	MCCLELLAN AIR FORCE BASE	1.08
	MONTEREY AREA	1.11
	OAKLAND ARMY BASE	1.17
	PORT HUENEME AREA	1.05
	RIVERBANK ARMY AMMO PLANT	1.09
	SACRAMENTO ARMY DEPOT	1.05
	SHARPE ARMY DEPOT	1.12
	SIERRA ARMY DEPOT	1.44
	STOCKTON AREA	1.04
	TRAVIS AIR FORCE BASE	1.23
	VANDENBERG AIR FORCE BASE	1.25
	29 PALMS MARINE CORPS BASE	1.32
COLORADO		1.02
	COLORADO SPRINGS	1.02
	DENVER	1.02
	AIR FORCE ACADEMY	1.02
	CHEYENNE MOUNTAIN	1.06
	FALCON AIR FORCE STATION	1.06
	FITZSIMONS ARMY MED CENTER	1.03
	FORT CARSON	1.12
	PETERSON AIR FORCE BASE	1.02
	PUEBLO ARMY DEPOT	0.95
	ROCKY MOUNTAIN ARSENAL	1.03

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
CONNECTICUT		1.12
	BRIDGEPORT	1.13
	NEW LONDON	1.11
	NEW LONDON AREA	1.11
	STRATFORD ENG PLANT	1.13
DELEWARE		1.08
	DOVER	1.06
	WILMINGTON	1.09
	DOVER AIR FORCE BASE	1.03
FLORIDA		0.90
	MIAMI	0.94
	PANAMA CITY	0.85
	CAPE CANAVERAL	0.96
	EGLIN AIR FORCE BASE	0.86
	HOMESTEAD AIR FORCE BASE	0.94
	JACKSONVILLE AREA	0.90
	KEY WEST NAVAL AIR STATION	1.08
	MCDILL AIR FORCE BASE	0.84
	ORLANDO AREA	0.89
	PANAMA CITY AREA	0.85
	PENSACOLA AREA	0.88
	TYNDALL AIR FORCE BASE	0.85
GEORGIA		0.87
	ALBANY	0.80
	ATLANTA	0.93
	ALBANY AREA	0.82
	FORT BENNING	0.81
	FORT GILLEM	0.93
	FORT GORDON	0.85
	FORT MCPHERSON	0.93
	FORT STEWART	0.83
	KINGS BAY	0.92
	ROBINS AIR FORCE BASE	0.82
HAWAII		1.47
	HONOLULU	1.43
	KANEOHOE BAY	1.50
	BARBERS POINT NAVAL AIR STATION	1.50

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
	BARKING SANDS	1.67
	FORD ISLAND	1.64
	FORT DERUSSY	1.43
	FORT SHAFTER	1.45
	HICKAM AIR FORCE BASE	1.43
	KANEOHE MARINE CORPS AIR STATION	1.50
	PEARL HARBOR	1.45
	POHAKULOA	1.77
	SCHOFIELD BARRACKS	1.53
	TRIPLER ARMY MEDICAL CENTER	1.43
	WHEELER ARMY AIR FIELD	1.53
IDAHO		1.15
	BOISE	1.06
	MOUNTAIN HOME	1.23
	MOUNTAIN HOME AIR FORCE BASE	1.23
ILLINOIS		1.20
	BELLEVILLE	1.14
	CHICAGO	1.26
	FOREST PARK	1.26
	GLENVIEW	1.26
	GREAT LAKES (NTC)	1.26
	ROCK ISLAND ARSENAL	1.05
	SAVANNAH ARMY DEPOT	1.08
	SCOTT AIR FORCE BASE	1.22
INDIANA		1.01
	INDIANAPOLIS	1.04
	LOGANSPORT	0.98
	CRANE NWSC	1.05
	FORT BENJAMIN HARRISON	1.06
	GRISSOM AIR FORCE BASE	1.06
	JEFFERSON PROVING GROUND	0.96
IOWA		1.07
	BURLINGTON	1.14
	DES MOINES	1.00
	IOWA ARMY AMMO PLANT	1.21

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
KANSAS		0.94
	MANHATTAN	0.94
	WICHITA	0.94
	FORT LEAVENWORTH	1.08
	FORT RILEY	1.06
	KANSAS ARMY AMMO PLANT	0.92
	MCCONNELL AIR FORCE BASE	0.94
KENTUCKY		0.92
	LEXINGTON	0.91
	LOUISVILLE	0.93
	FORT CAMPBELL	1.02
	FORT KNOX	0.96
	LEXINGTON/BLUE GRASS AD	0.98
	LOUISVILLE NAVAL AIR STATION	0.93
LOUISIANA		0.90
	NEW ORLEANS	0.93
	SHREVEPORT	0.86
	BARKSDALE AIR FORCE BASE	0.86
	FORT POLK	0.94
	LOUISIANA ARMY AMMO PLANT	0.85
	NEW ORLEANS ARMY BASE	0.93
MAINE		1.02
	BANGOR	1.07
	PORTLAND	0.97
	BRUNSWICK AREA	0.95
	CUTLER WINTER HARBOR	0.95
MARYLAND		0.87
	BALTIMORE	0.87
	LEXINGTON PARK	0.86
	ABERDEEN PROVING GROUND	0.87
	ANDREWS AIR FORCE BASE	0.96
	ANNAPOLIS	0.87
	BETHESDA	0.96
	CHELTONHAM (D.C.)	0.96
	CHESAPEAKE BEACH	0.89
	FORT DETRICK	0.87
	FORT GEORGE G. MEADE	0.87

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
	FORT RITCHIE	0.87
	HARRY DIAMOND LAB	0.96
	INDIAN HEAD	0.88
	PATUXENT RIVER AREA	0.86
	THURMONT	0.87
MASSACHUSETTS		1.19
	BOSTON	1.24
	FITCHBURG	1.14
	ARMY MAT & MECH LAB	1.12
	FORT DEVENS	1.27
	HANSCOM AIR FORCE BASE	1.20
MICHIGAN		1.16
	DETROIT	1.15
	MARQUETTE	1.16
	DETROIT ARSENAL	1.15
	K I SAWYER AIR FORCE BASE	1.16
MINNESOTA		1.24
	DULUTH	1.22
	MINNEAPOLIS	1.26
MISSISSIPPI		0.84
	BILOXI	0.84
	COLUMBUS	0.83
	COLUMBUS AIR FORCE BASE	0.83
	GULFPORT AREA	0.85
	KEESLER AIR FORCE BASE	0.83
	MERIDIAN NAVAL AIR STATION	0.88
MISSOURI		0.99
	KANSAS CITY	1.04
	SEDALIA	0.93
	FORT LEONARD WOOD	1.11
	LAKE CITY ARMY AMMO PLANT	1.06
	ST. LOUIS ARMY AMMO PLANT	1.10
	WHITEMAN AIR FORCE BASE	1.04

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
MONTANA		1.20
	BILLINGS	1.17
	GREAT FALLS	1.23
	MALMSTROM AIR FORCE BASE	1.16
NEBRASKA		0.93
	GRAND ISLAND	0.88
	OMAHA	0.97
	CORNHUSKER ARMY AMMO PLANT	0.86
	OFFUTT AIR FORCE BASE	0.97
NEVADA		1.10
	HAWTHORNE	1.14
	LAS VEGAS	1.05
	FALLON	1.25
	HAWTHORNE ARMY AMMO PLANT	1.13
	NELLIS AIR FORCE BASE	1.06
NEW HAMPSHIRE		1.06
	CONCORD	1.07
	PORTSMOUTH	1.05
	PORTSMOUTH AREA	1.05
NEW JERSEY		1.15
	NEWARK	1.16
	TRENTON	1.14
	BAYONNE MOT	1.15
	EARLE	1.15
	FORT DIX	1.11
	FORT MONMOUTH	1.10
	MCGUIRE AIR FORCE BASE	1.14
	PICATINNY ARSENAL	1.20
NEW MEXICO		1.02
	ALAMOGORDO	1.02
	ALBUQUERQUE	1.01
	CANNON AIR FORCE BASE	1.03
	HOLLOMAN AIR FORCE BASE	0.98
	KIRTLAND AIR FORCE BASE	0.96
	WHITE SANDS MR	1.03

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
NEW YORK		1.18
	ALBANY	1.05
	NEW YORK CITY	1.30
	FORT DRUM	1.12
	GRIFFISS AIR FORCE BASE	1.04
	NIAGARA	1.20
	PLATTSBURGH AIR FORCE BASE	1.07
	SENECA ARMY DEPOT	1.08
	STATEN ISLAND	1.24
	U.S. MILITARY ACADEMY	1.23
	WATERVLIET ARSENAL	1.00
NORTH CAROLINA		0.84
	FAYETTEVILLE	0.83
	GREENSBORO	0.84
	CAMP LEJEUNE AREA	0.90
	CHERRY	0.92
	FORT BRAGG	0.86
	NEW RIVER	0.91
	POPE AIR FORCE BASE	0.86
	SEYMOUR JOHNSON AFB	0.82
	SUNNY POINT	0.91
NORTH DAKOTA		1.03
	GRAND FORKS	0.98
	MINOT	1.08
	MINOT AIR FORCE BASE	1.08
OHIO		0.97
	DAYTON	0.96
	YOUNGSTOWN	0.97
	RAVENNA ARMY AMMO PLANT	0.96
	WRIGHT-PATTERSON AFB	0.96
OKLAHOMA		0.90
	LAWTON	0.92
	OKLAHOMA CITY	0.88
	ALTUS AIR FORCE BASE	1.00
	FORT SILL	0.95
	MCALESTER ARMY AMMO PLANT	0.86
	TINKER AIR FORCE BASE	0.88

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
	VANCE AIR FORCE BASE	0.92
OREGON		1.11
	PENDLETON	1.16
	PORTLAND	1.05
	UMATILLA ARMY DEPOT	1.19
PENNSYLVANIA		1.04
	PHILADELPHIA	1.09
	PITTSBURGH	0.99
	CARLISLE BARRACKS	0.97
	INDIANTOWN GAP MR	1.04
	LETTERKENNY ARMY DEPOT	1.02
	MECHANICBURG AREA	0.97
	NEW CUMBERLAND ARMY DEPOT	0.97
	PHILADELPHIA AREA	1.09
	TOBYHANNA ARMY DEPOT	1.06
	WARMINSTER	1.05
RHODE ISLAND		1.07
	NEWPORT	1.09
	PROVIDENCE	1.04
SOUTH CAROLINA		0.87
	CHARLESTON	0.88
	COLUMBIA	0.86
	BEAUFORT AREA	0.97
	CHARLESTON AIR FORCE BASE	0.88
	FORT JACKSON	0.86
	SHAW AIR FORCE BASE	0.86
SOUTH DAKOTA		0.99
	RAPID CITY	1.00
	SIOUX FALLS	0.97
	ELLSWORTH AIR FORCE BASE	1.02
TENNESSEE		0.85
	CHATTANOOGA	0.83
	MEMPHIS	0.87
	ARNOLD AIR FORCE BASE	0.94
	VOLUNTEER ORDINANCE WORKS	0.81

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
	MEMPHIS NAVAL AIR STATION	0.96
TEXAS		0.82
	SAN ANGELO	0.81
	SAN ANTONIO	0.82
	BROOKS AIR FORCE BASE	0.82
	CAMP BULLIS	0.82
	CORPUS CHRISTI AREA	0.92
	DALLAS	0.94
	DYESS AIR FORCE BASE	0.86
	FORT BLISS	0.95
	FORT HOOD	0.85
	FORT SAM HOUSTON	0.82
	GOODFELLOW AIR FORCE BASE	0.81
	KELLY AIR FORCE BASE	0.82
	KINGSVILLE AREA	0.93
	LACKLAND AIR FORCE BASE	0.82
	LAUGHLIN AIR FORCE BASE	1.01
	LONE STAR ARMY AMMO PLANT	0.85
	LONGHORN ARMY AMMO PLANT	0.85
	RANDOLPH AIR FORCE BASE	0.82
	RED RIVER ARMY DEPOT	0.85
	REESE AIR FORCE BASE	0.87
	SHEPPARD AIR FORCE BASE	0.94
	INGLESIDE NAVAL STATION	0.95
UTAH		0.97
	OGDEN	0.98
	SALT LAKE CITY	0.96
	DOUGWAY PROVING GROUND	1.04
	FORT DOUGLAS	0.96
	HILL AIR FORCE BASE	0.98
	TOOELE ARMY DEPOT	1.06
VERMONT		0.88
	BURLINGTON	0.86
	MONTPELIER	0.89
VIRGINIA		0.90
	NORFOLK	0.91
	RICHMOND	0.88

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
	DAHLGREN	0.92
	FORT A P HILL	0.88
	FORT BELVOIR	0.96
	FORT EUSTIS	0.91
	FORT LEE	0.91
	FORT MONROE	0.91
	FORT MYER	0.96
	FORT PICKETT	0.94
	FORT STORY	0.91
	LANGLEY AIR FORCE BASE	0.91
	QUANTICO	0.96
	RADFORD ARMY AMMO PLANT	0.95
	VINT HILL FARMS	0.92
WASHINGTON		1.10
	SPOKANE	1.09
	TACOMA	1.10
	BREMERTON	1.09
	EVERETT	1.09
	FAIRCHILD AIR FORCE BASE	1.05
	FORT LEWIS	1.10
	INDIAN HEAD	1.09
	MCCHORD AIR FORCE BASE	1.10
	SILVERDALE	1.06
	WHIDBEY ISLAND	1.09
	YAKIMA FIRING RANGE	1.04
WEST VIRGINIA		0.96
	BLUEFIELD	0.96
	CHARLESTON	0.96
	SUGAR GROVE	1.40
WISCONSIN		1.10
	MADISON	1.09
	MILWAUKEE	1.11
	BADGER ARMY AMMO PLANT	1.16
	FORT MCCOY	1.15
WYOMING		0.98
	CASPER	0.97
	CHEYENNE	0.98

Part I - U.S. Locations

STATE	LOCATION	ACF INDEX
	F E WARREN AIR FORCE BASE	0.98
WASHINGTON DC		0.96
	BOLLING AIR FORCE BASE	0.96
	FORT MCNAIR	0.96
	WALTER REED ARMY MED CENTER	0.96

Part II - OCONUS Locations

NATION	LOCATION	ACF INDEX
ANTIGUA		1.77
	ANTIGUA	1.77
AUSTRALIA		1.49
	DARWIN	1.84
	PERTH	1.36
	SYDNEY	1.32
	WOOMERA AS	1.43
AZORES		1.24
	LAGES	1.24
BAHAMAS		1.67
	ANDROS ISLAND	1.67
BAHRAIN		1.56
	BAHRAIN	1.56
BELGIUM		1.35
	BRUSSELS	1.35
BERMUDA		1.55
	BERMUDA	1.55
CANADA		1.31
	ARGENTINA/NEWFOUNDLAND	1.31
CUBA		1.51
	GUANTANAMO	1.51
DIEGO GARCIA		2.43
	DIEGO GARCIA	2.43
EGYPT		1.27
	CAIRO	1.27
GERMANY		1.49
	FRANKFURT	1.58
	KAISERSLAUTERN	1.54
	TRIER	1.34

Part II - OCONUS Locations

NATION	LOCATION	ACF INDEX
GREECE		0.77
	ATHENS	0.77
GREENLAND		3.29
	GODHAAB (WUUK)	3.29
GUAM		2.01
	GUAM	2.01
ICELAND		3.20
	REYKJAVIK	3.20
ITALY		1.17
	ISOLA DI CAPO RIZZUTO	1.15
	LA MADDALENA	1.22
	NAPLES	1.16
	SIGNOLLA	1.19
	VENICE	1.14
JAPAN		1.63
	ATSUGI	1.73
	MISAWA	1.59
	OKINAWA	1.53
	TOKYO	1.73
	IWAKUNI	1.56
JOHNSTON ATOLL		2.13
	JOHNSTON ATOLL	2.13
KOREA		1.16
	CHINHAE	1.18
	DMZ ZONE AREA	1.23
	KUNSAN	1.17
	OSAN	1.17
	SEOUL	1.07
KWAJALEIN		2.20
	KWAJALEIN	2.20
MIDWAY ISLAND		1.99
	MIDWAY ISLAND	1.99

Part II - OCONUS Locations

NATION	LOCATION	ACF INDEX
MOROCCO		1.18
	CASABLANCA	1.18
NETHERLANDS		1.15
	OSS	1.15
NEW ZEALAND		2.46
	WELLINGTON	2.46
OMAN		1.37
	RUWI	1.37
PANAMA		1.08
	PANAMA CITY	1.08
PHILIPPINES		0.69
	MANILA	0.68
	SUBIC BAY	0.69
PUERTO RICO		1.05
	SAN JUAN	1.05
SEYCHELLES ISLAND		2.23
	SEYCHELLES ISLAND	2.23
SPAIN		1.04
	ROTA	1.04
TURKEY		0.80
	ANKARA	0.80
	INCIRLIK	0.80
UNITED KINGDOM		1.36
	LONDON	1.38
	MANCHESTER	1.30
	ST MAWGAN	1.37
	EDZELL, SCOTLAND	1.39

Appendix B: User's Manual

The purpose of this User's Manuel is to provide the user with a step by step guide through the determination of the Least Cost Combination of Housing for an Air Force Installation. The entire model is an Excel spreadsheet in which the data can be entered. The only sheet of this model that the user needs input data on is Sheet1 titled "Input&Results." The calculations in the rest of the model are performed using the data from "Input&Results" (Sheet1).

Once the Least Cost Combination of Housing has been determined, Sheet2 titled "Test Sheet" can be used to investigate changes in the input variables for any particular group of housing. Once the variables for the group of housing is entered in the "Test Sheet," a graph of the costs for the next 65 years on that group of housing is produced on the third sheet of the model titled "Yearly Housing Cost." Sheet4 of the model titled "Zoom on Maint. Cost" will zoom in on the maintenance costs displayed in the graph on Sheet3 "Yearly Housing Cost." An explanation of the "Test Sheet" will follow the "Input&Results" explanation.

The data necessary for this analysis is listed in section 3.4 of this thesis. Some of the data necessary must be provided by the Installation being studied, and some of the data can default to Air Force averages.

STEP #1 - Open the Overall Model in Microsoft Excel

If the model does not open to cell A1 in Sheet1 titled "Input&Results," then go to cell A1 of the sheet titled "Input&Results."

The user should see the following spreadsheet:

INPUT FOR THE MODEL		Cost of Optimal Comb. =	$38,681,074.77
Variables that Effect the entire model:		Current Strategy Cost =	$41,079,305.01
Area Cost Factor =	1.21		
interest rate =	0.063		
inflation rate =	0.025		
Military Yearly Increase in BAQ&VHA =	0.03		
Variables that effect the individual models:	**E1-E3**		
Construction Cost of New =	139000.00	**BAQ+VHA =**	460
Revitalization Cost =	102000.00	**Housing Factor =**	0.88
Average Maintenance Cost =	3096		
Demolition Cost =	8000		
Number of Families =	467	Current Strategy On-Base Cost =	$2,244,381.94
Number of Mission Essential Families =	0	Current Strategy Off-Base Cost =	$407,839.42
Available Off-Base Housing =	447	Current Strategy E1-E3 Cost =	$2,652,221.36
Up to EIGHT different groups of Housing:	**1**	**2**	**3**
Age of the Existing Housing =	53	39	47
Years since last Revitalization =	10	39	15
Next Revitalization Due =	11	0	6
Years until next Revitalization =	0	0	0
Available On-Base Housing =	1	19	55
On-Base Housing to be Used =	0	0	0
	House Off	House Off	House Off
Annual Cost Per House =	15499.54	18514.58	17377.75
Total =	$0.00	$0.00	$0.00

Enter Global Variables

STEP #2 - Input the Area Cost Factor

The Area Cost Factor should be entered into cell B4 of "Input&Results"
Recommended Value = see Appendix A

***It is important to note that the Area Cost Factor will not be used if the user will be using local Construction Costs, Revitalization Costs, and Maintenance Costs. **If the user is using local costs, an Area Cost Factor of 1.00 should be used**. This is because local costs have already accounted for the increase or decrease in the area's cost compared to the national average. If the recommended Air Force averages are used, the Area Cost Factor can be found in Appendix A.

STEP #3 - Input the Interest Rate

The Interest Rate should be entered into cell B5 of "Input&Results"
Recommended Value = 0.063

STEP #4 - Input the Inflation Rate

The Inflation Rate should be entered into cell B6 of "Input&Results"
Recommended Value = 0.025

STEP #5 - Input the Military Yearly Increase in BAQ & VHA

The Military Yearly Increase in BAQ & VHA should be entered into cell B7 of "Input&Results"
Recommended Value = 0.03

Enter Local Variables - E1-E3

STEP #6 - Input the Construction Cost of a New Home for Rank Category E1-E3

The Construction Cost of a New Home for this category should be entered into cell B10 of "Input&Results"
Recommended Value = 139,000

STEP #7 - Input the Revitalization Cost of a Home for Rank Category E1-E3

The Revitalization Cost of a Home for this category should be entered into cell B11 of "Input&Results"
Recommended Value = 102,000

STEP #8 - Input the Average Maintenance Cost of a Home for Rank Category E1-E3

The Average Maintenance Cost of a Home for this category should be entered into cell B12 of "Input&Results"
Recommended Value = 3,096

STEP #9 - Input the Demolition Cost of an Existing House for the Rank Category E1-E3

The Demolition Cost of a house for this category should be entered into cell B13 of "Input&Results"
Recommended Value = 8,000

STEP #10 - Input the Number of Families for Rank Category E1-E3

The Number of Families for this category should be entered into cell B14 of "Input&Results"
Recommended Value = Base Dependent (can be found in HMA)

STEP #11 - Input the Number of Mission Essential Families for Rank Category E1-E3

The Number of Mission Essential Families for this category should be entered into cell B15 of "Input&Results"
Recommended Value = Base Dependent (can be found in HMA)

STEP #12 - Input the Number of Available Off-Base Housing Units for Rank Category E1-E3

The Number of Available Off-Base Housing Units for this category should be entered into cell B16 of "Input&Results"
Recommended Value = Base Dependent (can be found in HMA)

STEP #13 - Input the Average Amount of BAQ & VHA for Rank Category E1-E3

The Average Amount of BAQ & VHA for this category should be entered into cell D10 of "Input&Results"
Recommended Value = Base Dependent (can be found at the Military Pay Office)

STEP #14 - Input the Housing Factor for Rank Category E1-E3

The Housing Factor for this category should be entered into cell D11 of "Input&Results"
Recommended Value = 0.88

***It is important to note that the Housing Factor will not be used if the user will be using known Construction and Revitalization costs for this category's housing. **If the user is using Known costs, a Housing Factor of 1.00 should be used.** If the recommended Air Force averages are used, the Housing Factor recommended above should be used.

STEP #15 - Input the Age of the Existing Housing for Rank Category E1-E3

The Age of the first group of Existing Housing for this category should be entered into cell B20 of "Input&Results." Up to 8 groups of housing can be analyzed using cells B20-I20.
Recommended Value = Base Dependent (can be found in Real Property Records)

STEP #16 - Input the Years Since Last Revitalization for Rank Category E1-E3

The number of years since the last revitalization of the housing group that corresponds to the age entered in cell B20 should be entered into cell B21 of "Input&Results." Up to 8 groups of housing can be analyzed using cells B21-I21. If the housing's Revitalization schedule has been following the Air Force Policy, then a default value of zero can be used.
Recommended Value = Base Dependent (can be found in Real Property Records)

STEP #17 - Input the Number of Available On-Base Housing Units for Rank Category E1-E3

The number of available On-Base Housing Units that corresponds to the housing group's whose age was entered in cell B20 should be entered into cell B24 of "Input&Results." Up to 8 groups of housing can be analyzed using cells B24-I24.
Recommended Value = Base Dependent (can be found at Base Housing Office or Real Property Records)

STEP #18 - Repeat Steps 6-16 for all Rank Categories

Simply scroll down the spreadsheet to the appropriate cells in which to enter the same variables. The layout for all rank categories is exactly the same as E1-E3, except that categories O1-O3, O4-O5, and O6-UP can only handle up to 4 groups of On-Base Housing. All recommendations are the same except the Housing Factors. The recommended housing Factors are listed below.

O6-UP -	**1.33**
O4-O5 -	**1.04**
O1-O3 -	**0.93**
E7-E9 -	**0.93**
E4-E6 -	**0.88**
E1-E3 -	**0.88**

STEP #19 - Input the Years Until Next Revitalization for all housing groups

This variable allows for the Revitalization of a group of housing to be delayed if needed. Once all of the data for a housing group is entered, there will be a number calculated in the cell above this variable titled "Next Revitalization Due." When a zero is entered into this variable's cell, the cost of maintaining that particular group of housing will be calculated assuming that the recommendation in "Next Revitalization Due" is followed. If a delay in the revitalization is desired, a larger number than the one recommended can be used.
Recommended Value = 0

STEP #20 - Identify the results of the model

The spreadsheet that makes up the model will recalculate itself as the data is entered into the appropriate cells. Once all data has been entered, the annualized cost produced in cell D1 will be an accurate expected annualized cost of the Least Cost Combination of Housing for the Air Force Installation under study. This cost can be compared to the expected annualized cost of the current Air Force Housing Strategy in cell D3.

The combination recommended for housing rank category E1-E3 is shown in cells A32-D35 and looks like this:

Off-Base & Demolition Cost of Unused Housing =	$1,739,515.76	Housed Off-Base =	167
On-Base Cost =	$0.00	Housed On-Base =	0
Cost Building New =	$0.00	Houses to Build =	0
Total Cost For E1-E3 =	$1,739,515.76		167

A similar summary can be found under each rank category. In addition to this summary, a recommendation is given under each housing group to tell the user whether or not to use the existing housing. Combining all of the summaries, the optimal combination of housing is determined for the Installation. The ability to change the variables to apply to any location allows any Installation to be analyzed.

USING THE "TEST SHEET"

STEP #1 - Go to the "Test Sheet"

Click on the sheet tab at the bottom of the spreadsheet titled "**Test Sheet**." Clicking on this tab should take you to Cell B136 in the second sheet of the spreadsheet. If it does not, then go to Cell B136 of Sheet2 titled "Test Sheet."

The user should see the following spreadsheet:

		COST YEAR 1	YEAR 2	YEAR 3	YEAR 4
		310893.10	174231.72	177859.66	181565.47
		19962.58	11187.50	11420.45	11658.40
Demolition Cost =	9000				
Construction Cost of New =	139000.00	BAQ+VHA =	460	Housing Factor =	0.89
Revitalization Cost =	102000.00	Annual =	5520	Area Cost Factor =	1.21
Average Maintenance Cost =	3096	TOTAL =	164597.22		
First Year Maint. Cost =	2490	annualized =	10568.86		
Interest rate =	0.063				
Inflation rate =	0.025				
Military Yearly Increase in BAQ&VHA =	0.03				
Age of the Existing Housing =	55	Mod. Age of House =	55.00		
Next Ren. should be in =	13.00	(Mod) Next Ren. should be in =	11		
Years until next Renovation =	0		2.00		
Years since last Renovation =	10	Last Ren. should have been =	8.00		
		Diff in Yrs since last Ren.			
		& actual last Renovation =	2.00		
	COST	ANNUALIZED			
Build New Housing =	310893.10	19962.58			
Maintain Existing Housing =	241386.55	15499.64			
House Off-Base =	164597.22	10568.86			

STEP #2 - Input the Variables

The variables that need to be entered into this sheet are the cells shaded in **BLUE**. **ONLY THE BLUE SHADED CELLS SHOULD BE CHANGED**. These variables will be the same that were entered for a particular group of housing on Sheet1 "Input&Results." The **YELLOW** shaded cells are the output of the sheet and identify the annualized cost of each housing option. The variables that need to be entered are discussed below.

Enter Global Variables

STEP #3 - Input the Area Cost Factor

The Area Cost Factor should be entered into cell F138 of "Test Sheet"
Recommended Value = see Appendix A

***It is important to note that the Area Cost Factor will not be used if the user will be using local Construction Costs, Revitalization Costs, and Maintenance Costs. **If the user is using local costs, an Area Cost Factor of 1.00 should be used.** This is because local costs have already accounted for the increase or decrease in the area's cost compared to the national average. If the recommended Air Force averages are used, the Area Cost Factor can be found in Appendix A.

STEP #4 - Input the Interest Rate

The Interest Rate should be entered into cell B141 of "Test Sheet"
Recommended Value = 0.063

STEP #5 - Input the Inflation Rate

The Inflation Rate should be entered into cell B142 of "Test Sheet"
Recommended Value = 0.025

STEP #6 - Input the Military Yearly Increase in BAQ & VHA

The Military Yearly Increase in BAQ & VHA should be entered into cell B143 of "Test Sheet"
Recommended Value = 0.03

Enter Local Variables - any particular housing group

STEP #7 - Input the Demolition Cost of an Existing House

The Demolition Cost of an Existing House should be entered into cell B136 of "Test Sheet"
Recommended Value = $8,000

STEP #8 - Input the Construction Cost of a New Home

The Construction Cost of a New Home should be entered into cell B137 of "Test Sheet"
Recommended Value = 139,000

STEP #9 - Input the Revitalization Cost of a Home

The Revitalization Cost of a Home should be entered into cell B138 of "Test Sheet"
Recommended Value = 102,000

STEP #10 - Input the Average Maintenance Cost of a Home

The Average Maintenance Cost of a Home should be entered into cell B139 of "Test Sheet"
Recommended Value = 3,096

STEP #11 - Input the Average Amount of BAQ & VHA for the Rank Category

The Average Amount of BAQ & VHA should be entered into cell D137 of "Test Sheet"
Recommended Value = Base Dependent (can be found at the Military Pay Office)

STEP #12 - Input the Housing Factor for the Rank Category

The Housing Factor for the category should be entered into cell F137 of "Test Sheet"
Recommended Value =

O6-UP -	**1.33**
O4-O5 -	**1.04**
O1-O3 -	**0.93**
E7-E9 -	**0.93**
E4-E6 -	**0.88**
E1-E3 -	**0.88**

***It is important to note that the Housing Factor will not be used if the user will be using known Construction and Revitalization costs for this category's housing. **If the user is using Known costs, a Housing Factor of 1.00 should be used.** If the recommended Air Force averages are used, the Housing Factor recommended above should be used.

STEP #13 - Input the Age of the Existing Housing in the housing group

The Age of the Existing Housing should be entered into cell B145 of "Test Sheet."
Recommended Value = Base Dependent (can be found in Real Property Records)

STEP #14 - Input the Years Since Last Revitalization for the housing group

The number of Years Since the Last Revitalization should be entered into cell B149 of "Test Sheet." If the housing's Revitalization schedule has been following the Air Force Policy, then a default value of zero can be used.
Recommended Value = Base Dependent (can be found in Real Property Records)

STEP #15 - Input the Years Until Next Revitalization

This variable allows for the Revitalization to be delayed if needed. Once all of the data for the housing group is entered, the **Years Until the Next Revitalization is Due** will be calculated in Cell D146. Entering a zero into Cell B147 for Years Until Next Revitalization will default to the recommended number of years. If a delay in the revitalization is desired, a larger number than the one recommended can be used.
Recommended Value = 0

STEP #16 - Identify the Least Cost Option

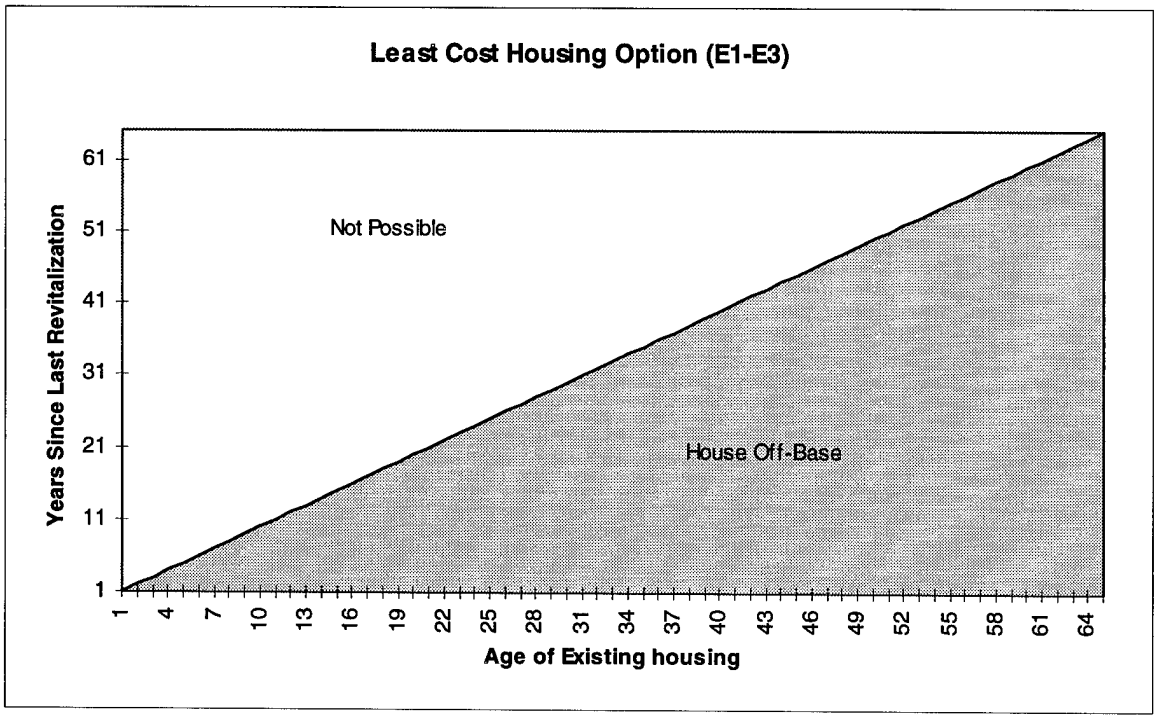
The least cost option for this group of housing will be the **smallest** of the three annualized costs calculated in the Yellow Cells. Changing any of the variables discussed above will change the outcome of the results, so this "Test Sheet" can be used to form the sensitivity analysis graphs discussed in Chapter 4.

STEP #17 - Track the cost maintaining the housing in the "Test Sheet"

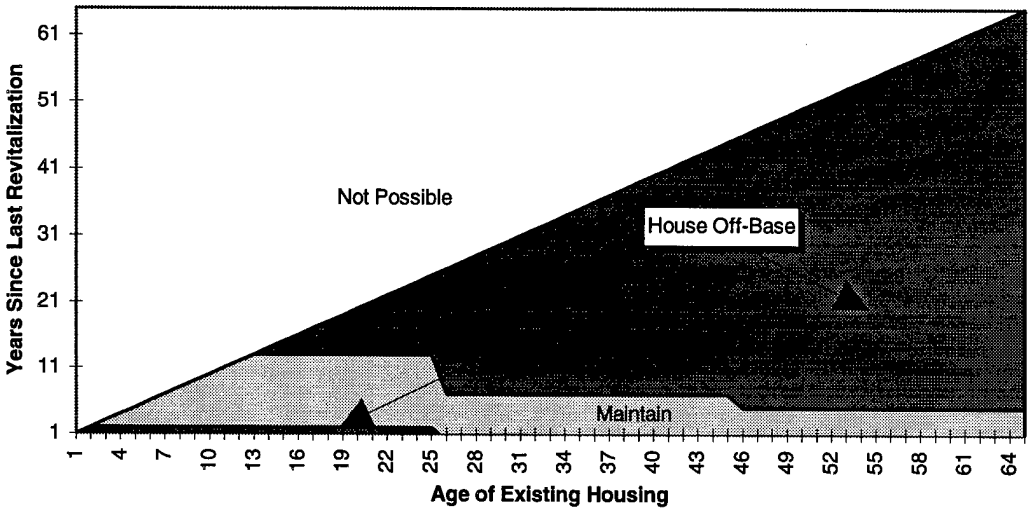
The graph produced the sheet titled "Yearly Housing Costs" shows the yearly cost of maintaining the housing group in the "Test Sheet." It presents the user with the real cost in each year over the next 65 years for one house in the housing group. The graph on Sheet4 titled "Zoom on Maint. Cost" allows the user to zoom in on the hard to read values of the "Yearly Housing Cost" graph.

Appendix C: Two-way Sensitivity Analysis Graphs

The two-way sensitivity analysis graphs on **Age of Existing Housing** and **Years Since Last Revitalization** are presented in this Appendix. The explanation of two-way sensitivity analysis can be found in section 4.3. The following graphs apply to Edwards Air Force Base for the respective Rank Categories.



Least Cost Housing Option (E4-E6)



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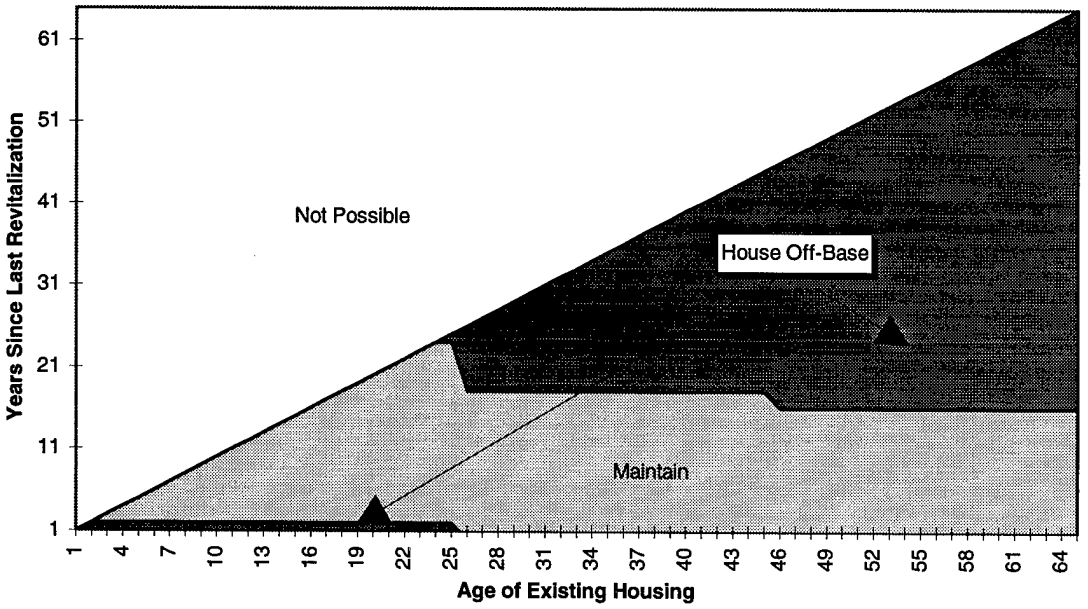

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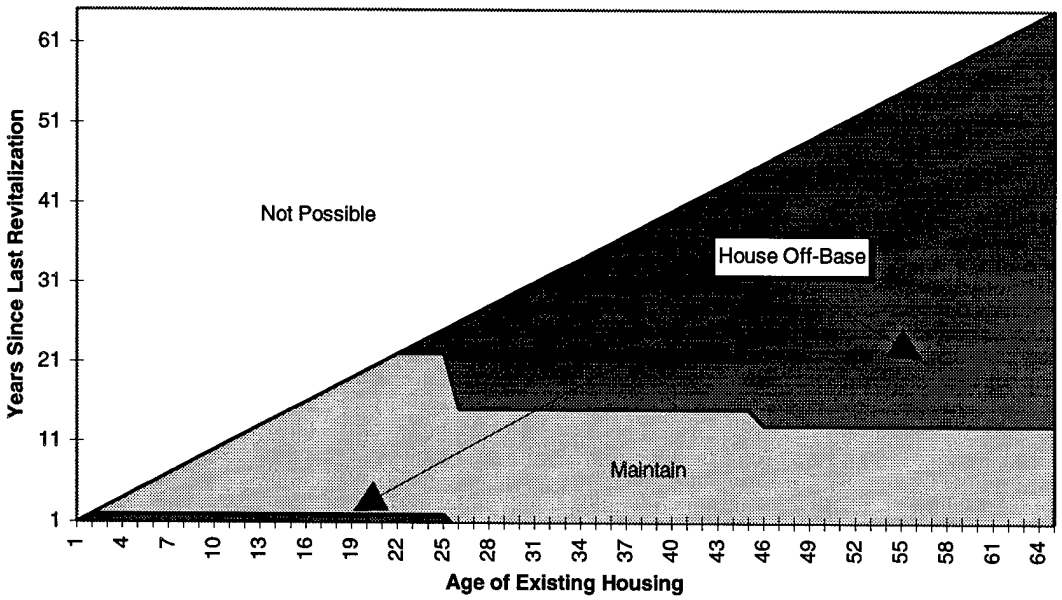

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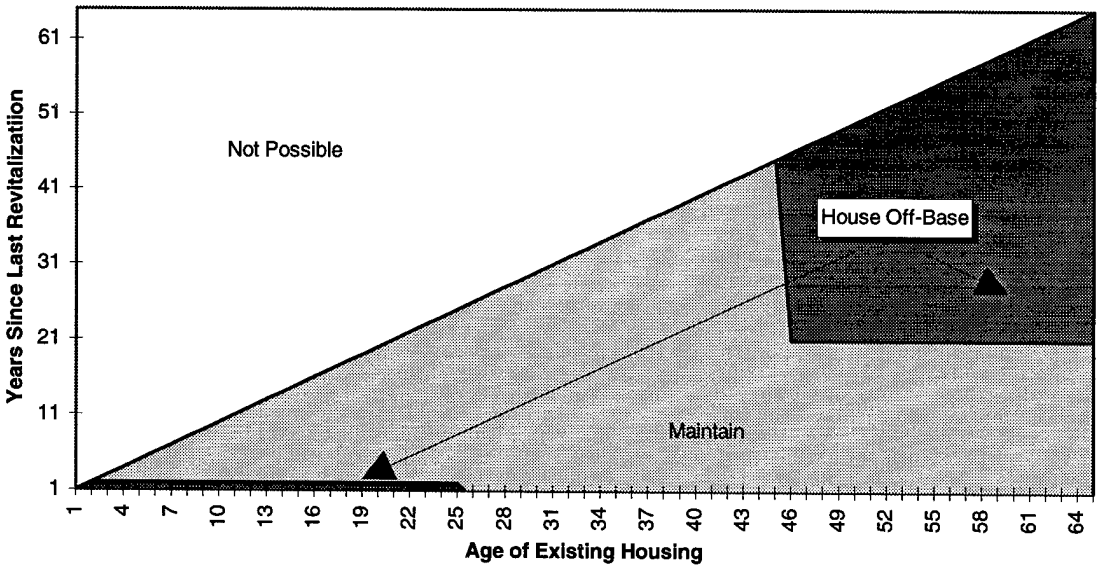

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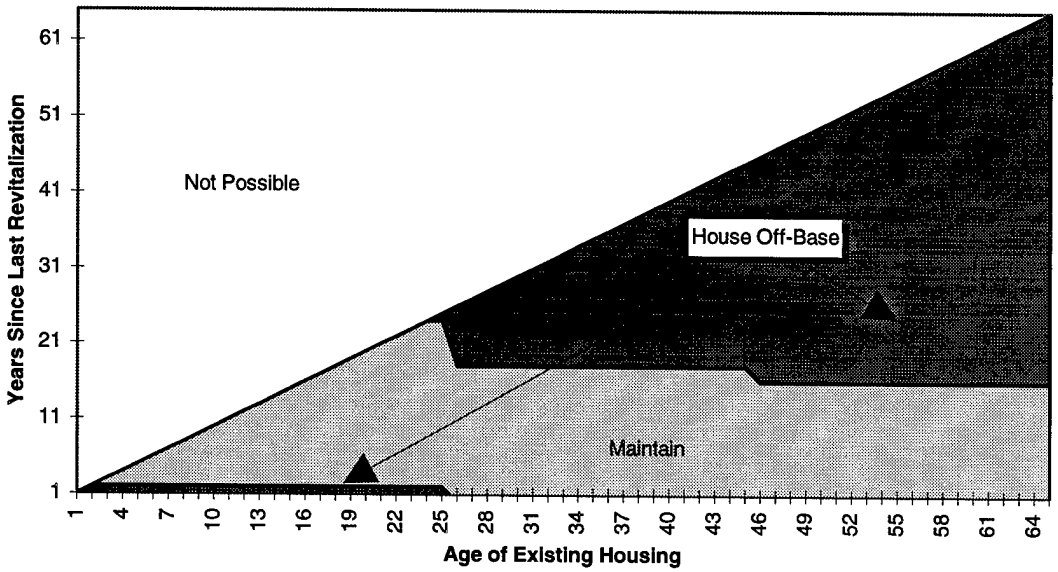

Vita

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13. ABSTRACT *(Maximum 200 words)*

The United States Military is faced with the decision of how to house it's military members and their families. The three options available to house these families are: 1) utilize existing on-base housing; 2) build new on-base housing; or, 3) compensate a military family monetarily to find housing off-base. This research focused on the development of a tool to aid the decision maker in determining what combination of the three options is economically optimal for an individual Air Force Installation. The model developed incorporates the costs associated to the local area and conditions at the specific installation to determine the cost associated with each of the three housing options.

Current Air Force Policy is to house military families Off-Base once all existing housing On-Base is occupied. Only if the local community can not meet the housing requirements of the Air Force Installation will funds be appropriated to build new housing. This current policy forces housing decisions to be made without the benefit of understanding the economically optimal combination. The model developed identifies this optimal combination to the user, as well as the savings to Installation if it is used. By changing the input into the model, any Air Force Installation could identify the economically optimal housing strategy. Performing sensitivity analysis on the variables used in the decision process will display the effect of any changes in the value of the input variables. Overall, the model provides a decision tool that can be used to make better informed decisions and can be easily manipulated to produce the economically optimal combination of housing for any Air Force Installation.

14. SUBJECT TERMS
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